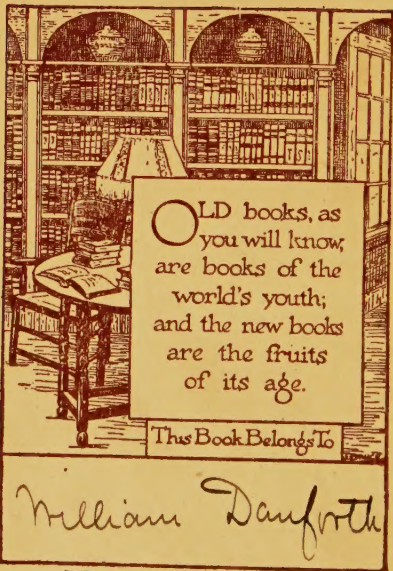


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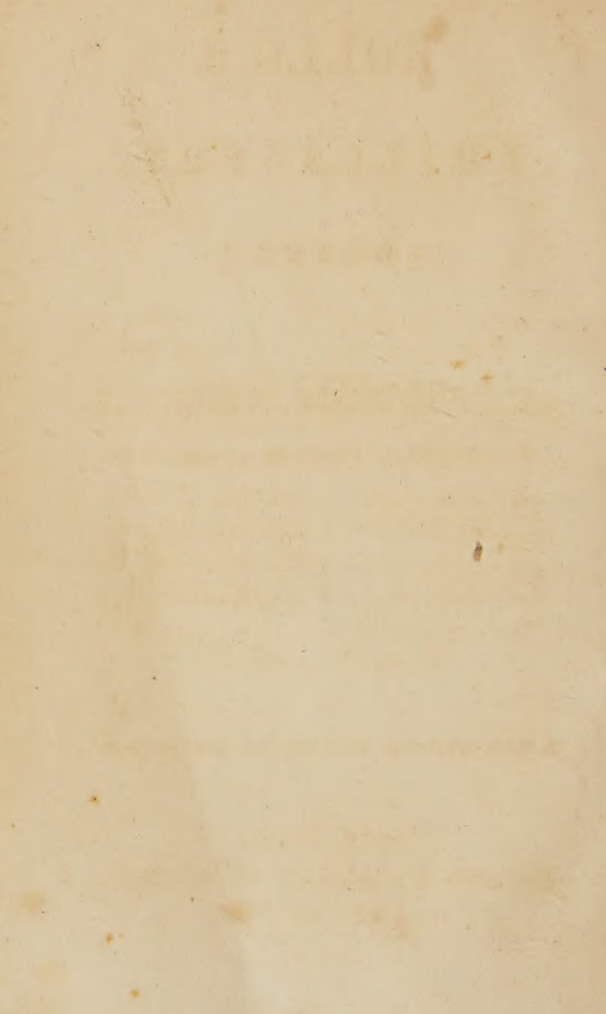


Willie Danforth

1870

Red Wing

Minnesota



ROLLO'S PHILOSOPHY.

[WATER.]

Jacob Abbott

THE ROLLO SERIES

IS COMPOSED OF FOURTEEN VOLUMES, VIZ

Rollo Learning to Talk.
Rollo Learning to Read.
Rollo at Work.
Rollo at Play.
Rollo at School.
Rollo's Vacation.
Rollo's Experiments.

Rollo's Museum.
Rollo's Travels.
Rollo's Correspondence.
Rollo's Philosophy—Water
Rollo's Philosophy—Air.
Rollo's Philosophy—Fire.
Rollo's Philosophy—Sky.

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P R E F A C E .

THE main design in view, in the discussions which are offered to the juvenile world, under the title of THE ROLLO PHILOSOPHY, relates rather to their effect upon the little reader's habits of thinking, reasoning, and observation, than to the additions they may make to his stock of knowledge. The benefit which the author intends that the reader shall derive from them, is an influence on the cast of his intellectual character, which is receiving its permanent form during the years to which these writings are adapted.

The acquisition of knowledge, however, though in this case a secondary, is by no means a unimportant, object ; and the discussion of the several topics proceeds accordingly, with regularity, upon a certain system of classification. This classification is based upon the more obvious external properties and relations of matter, and less upon those

which, though they are more extensive and general in their nature, and, therefore, more suitable, in a strictly-scientific point of view, for the foundations of a system, are less apparent, and require higher powers of generalization and abstraction; and are, therefore, less in accordance with the genius and spirit of the *Rollo* philosophy.

As teachers have, in some cases, done the author the honor to introduce some of the preceding works of this class into their schools, as reading books, &c., considerable reference has been had to this, in the form and manner of the discussion, and questions have been added to facilitate the use of the books in cases where parents or teachers may make the reading of them a regular exercise of instruction.

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THE ROLLO PHILOSOPHY

CHAPTER 1.

WATER.

IN the yard behind the house where Rollo lived, there stood a pump, with a sort of trough before it, made of planks, which was intended to conduct the waste water into a large hole in the ground before it. Rollo often wondered where the water came from, which was brought up by working the pump; and, also, where it went to, down in the hole at the end of the trough. He looked into the nose of the pump, but found that he could see in but a very little way. He also put his head down close to the hole. It was a square hole, with plank sides. It looked quite dark down there, but he thought he could see some stones at the bottom.

The trough had only three sides; the part towards the hole was of course left open,

so that the water might run off; and it was placed so as to be inclined towards the hole, in order that the water might run off more rapidly. Rollo had often tried to stop the water, by damming it up with stones; but, though he packed the stones as closely as he could, it *would* leak through, almost as fast as he could pump it in. At length Jonas, the boy who worked at his father's, told him that *he* would stop the water for him. So he took a measure, and measured the breadth of the side that was left open; then he went to the barn, and took a handsaw, and sawed off a piece of board, of exactly the right length to stop up the passage. The sides of the trough sloped towards each other a little, so that he could press it in tight; when it was fitted, Jonas pumped away, for some time, and Rollo was delighted to perceive that very little of the water escaped. The trough was soon filled with water, and it made Rollo quite a little pond.

Jonas looked around to the lower side of the board, and observed that there was quite a leak there, after all. "However," said he, "I'll calk it for you."

"*Calk* it?" said Rollo. "What is that?"

"Stop up the cracks, as they do in ships,"

said Jonas. "When they build ships, they drive something into the cracks very tight indeed, to prevent the water's leaking in."

So Jonas went into the shed, and presently returned with a rag. He tore off a long strip from this rag, and laid it down in the water, just above the board, and with a pointed stick he crowded it in, under the board. Thus he stopped the leak almost entirely; and he told Rollo that, by pumping a little now and then, he could easily keep the pond full; and so he could sail his boats there as long as he liked. He told him he might call it the Red Sea, if he pleased; for it happened that the outside of the trough was painted red. "It will be a very pretty amusement for you, for *one day*," said Jonas; "but that will be the end of it."

"Why," said Rollo, — "what do you mean by that?"

"O," said Jonas, "you will get your clothes all wet and muddy, and your mother will not let you play there again."

"Ho! — no I sha'n't," said Rollo.

"Yes you will," said Jonas, turning around and walking backwards. "Boys no bigger than you always like to play in the water better than anything else; but they have

not sense enough to be careful, and so they wet themselves all over. I am coming back in an hour, and I shall find you as wet as a fisherman."

Rollo said nothing ; he was putting little stones upon one of his wooden blocks, which he had taken for a vessel, and there was in his mind a mingled feeling of pleasure at seeing what a cargo his ship would carry, and of vexation that Jonas should think that he could not take care of himself any better.

His mother was sitting, all this time, at the window of her chamber, sewing, and she happened to see and to hear all that took place. She, however, said nothing, but occasionally looked up to see how Rollo went on. After about half an hour, she observed that he seemed to give up sailing his ships, and was stooping down, and looking at something very intently. He had a small stick in his hand, and he appeared to be doing something with that, which arrested his attention. His mother watched him for some time in silence, and at length said,

" Well, Rollo, what are you so much interested about ? "

Rollo looked up surprised ; and, when he saw his mother sitting at the window, he said,

"O mother, only see how this water jumps up I *wish* you would come down and see. Whenever I touch it very gently with this little stick, it jumps up to the stick."

"I am busy now," replied his mother, "and cannot come down; but you may bring up a little water to me, in a bowl, and show it to me here."

So Rollo went in, and got a bowl, and dipped up some of the water, and carried it very carefully up stairs to his mother. She told him that *he* must hold the bowl himself, for it was wet outside, and she would touch the water with the stick. She did so, and found that, whenever she touched it, the water would jump up, as Rollo termed it, to the stick, and rise in a little ridge all around it. But this ridge was very small indeed.

"What makes it do so, mother?" said Rollo.

"I don't know," said she.

"Don't you know, mother?" said he, with surprise. Rollo was always somewhat surprised to find any limits to his mother's knowledge.

"No," said she, "I don't know what

makes it. I knew that it *would* do so, and I knew several other facts analogous to it. I knew what name the philosophers gave to them all; but I do not know of any cause for them."

"Analogous?" said Rollo, musing, and looking a little at a loss.

"Yes; that is, similar in their nature. For instance," said she, "look here,—all around the edge of the water in the bowl."

Rollo looked, and saw that there was a little ridge of water raised against the side of the bowl, exactly like that around the stick.

He asked his mother what the reason was of such a strange appearance.

She answered that she could not tell what the reason of it was. She could only tell what it was called. She said it was called *attraction*.

"What is *attraction*, mother?" said Rollo.

"Attraction is *drawing together*. Whenever two things tend to come together, each drawing the other, it is called *attraction*. The magnet attracts the little needle which you hold up towards it; that is, they tend to come together. But if you roll two balls

toward one another upon the carpet, though they come together, they are not *attracted*, because neither of them has any influence on the other; they do not make each other move at all. You *roll* them together."

Rollo listened to all this very attentively, and then looked upon the bowl again. He did not exactly understand how his mother's explanation applied to the case of the water.

His mother saw that Rollo looked perplexed. "Don't you understand?" said she

"Not about the water's jumping up," he replied.

"Why, water attracts any thing that is brought very near it,—very near indeed. So, when you bring the stick down close to the water, it rises up a little all around the stick; which you call jumping up."

"Well, what makes it attract?" said Rollo.

"I don't know," said his mother; "you must ask your father to-night, at tea; and perhaps he can tell you. He knows a great deal more about it than I do."

Rollo carried his bowl down stairs carefully, and poured back the water into the Red Sea. When he had done so, he looked into the bowl, and found, as he might have

expected, that it was wet still. Some of the water remained on the inside of the bowl, running around in drops, as he turned the bowl in his hands. He stopped to look at it. It seemed to him strange, though he had never thought of it before, that the water did not all go out, and leave the bowl dry.

Just then, Dorothy came out of the kitchen to the pump, with her pail in her hand, to pump some water. She saw Rollo standing still, and looking into his bowl with an appearance of great attention, and said,

“Well, Rollo, what have you got now?”

Rollo did not answer; he was watching the little currents of water running round the inside of the bowl, as he turned it over and over.

“What are you looking at, Rollo?” she inquired again.

“O, I am looking at this bowl. See,” said he, “I turn it upside down, and yet all the water does not run out.”

“Why, yes it does,” said she.

“No,” said Rollo, “there is some left about the inside of the bowl. See,” he continued, pointing, “how wet it is.”

“Poh, it is only wet; all the water has



WHY DOESN'T THE WATER DROP OFF?—Page 17.

gone out, only the bowl is wet a little inside," she replied, pumping away into her pail.

"But is not *wet*, water?" said Rollo.

"Yes," said Dorothy, "I suppose it is."

"Then all the water does not fall out of the bowl, when I turn it upside down," persisted Rollo.

"Why, you silly child, that's nothing, I tell you. It always does so."

"But why doesn't it all drop out?" said Rollo, as she took off her pail from the nose of the pump, and walked towards the house. "See," he continued, following her, with the bowl in his hands; "I hold it bottom upwards; why doesn't the water drop off,—all of it? Answer me that, Dorothy; answer me that."

But Dorothy paid no attention to his question. She went into the house, and shut the door. The truth was, she would have found it somewhat difficult to "answer him that," and she seemed to think it most prudent not to attempt it. Rollo soon got tired of philosophizing alone, and went to sailing ships again, determined to ask his father that night at supper.

At length the sun went down, the day

drew near to its close, and Rollo found himself seated in the parlor ready for tea, — the setting sun shining beautifully in at the windows. His father came in, and they all took their seats at table; but Rollo had, for some time, no opportunity to bring forward the subject which interested him so much, for his father and mother were very busy talking about something else. Rollo would not interrupt them, but kept looking from time to time towards his father. His father at length observed him, and said,

“Rollo, have you got any thing to say to me?”

“Yes, sir,” said Rollo; “I want to show you an experiment, and have you explain it to me.”

Rollo then said he wanted to go out and get a bowl of water, and bring in to show his father what he meant; but his father, after hearing him describe it, said he thought he could show the experiment just as well with his cup of tea. So he brought down the spoon very slowly and carefully to the surface of the tea, and Rollo saw that the moment it touched, the tea immediately drew up around the spoon, just as the water had risen around his stick. “Yes,

father," said he, "that is the experiment, exactly. Now, please to explain it to me, father."

"Why, it is one of the properties of water to be attracted by almost any substance which comes very near it. But I suppose you do not know what I mean by *property*."

"Yes, sir, I do," said Rollo, eagerly,—"it means houses, and lands, and money."

Here Rollo made a great mistake. In fact, if he had not been so eager to show his knowledge, he might have perceived in a moment, that water could not have any houses, or lands, or money; and his father was speaking of the properties of *water*.

"That is one meaning," said his father. "When we are speaking of the property of *men*, we mean any thing that they possess. But when we speak of the properties of *things*, we mean something different. If I let the tongs drop upon the hearth, they do not break; they are strong. Strength is a property of the iron. So brittleness is a property of glass. It is a property of a magnet to attract iron. A property of any substance is a part of its nature, as the Creator has made it. Now, it is a property of water—that is, it is a part of its nature

—to attract almost any substance which comes very near it.”

“Mustn’t it touch it, father?” said Rollo.

“What we call touching it, is only coming very near it,—so near that we cannot see the distance between.”

“Why, father,” said Rollo, “is there any distance between when it touches?”

“Yes,” said his father, “very often; that is, in what we commonly *call* touching. Let me see,” said he, thinking; and here he turned and looked around the room. Presently he said,

“Ah, I see now.”

So he rose from the table, and took down a book from a little mahogany book-shelf behind him, and held it with the front edge towards Rollo.

“There, Rollo,” said he, “do the leaves of this book touch one another?”

“Yes, sir,” said Rollo.

Then his father pressed the covers together as hard as he could; and this crowded the leaves into a narrower space, although they had appeared to touch before.

“There; now you see,” he continued, “that they are nearer than they were before, though then they seemed to touch. So,

when you see any two things apparently touching one another, there may, after all, be a space between them."

"I did not know that before," said Rollo's mother.

"Yes," said his father, "I believe it is so. Therefore, Rollo, when I bring the spoon down to the water, at the instant that the water begins to rise up around it, it may be that there is a distance between, though I cannot perceive it."

Rollo was not quite satisfied. He thought he could see the spoon actually touch, before the water moved. However, his father told him that it was one of the properties of water to attract, and to be attracted by, almost all substances, when it came into apparent contact with them. This kind of attraction is called the *attraction of cohesion*.

"Cohesion?" said Rollo.

"Yes, the force with which the particles of the same or of different bodies are held together, is called, in general, *cohesion*. Though, if we wish to be precise, we call it *cohesion* only when speaking of the attraction which the particles of any one substance have for each other; and when we speak of the attraction which they

have for the particles of other bodies, we call it *adhesion*."

"And which is this?"

"Why, strictly it is adhesion; for it is between the tea, or rather the water of the tea, and the spoon. But, then, the particles of the drop itself which hangs down, are held together by cohesion. However, as the nature of the force, in the two cases, seems to be very nearly the same, it is generally all called the attraction of cohesion."

"But *why* does it attract, father?" said Rollo.

"No one knows of any reason, except that the Creator made it so."

"Does it do any good, father?"

"Yes," said his father. "It seems to you to be a very little thing, and to have, perhaps, no very useful tendency; and yet, were it not for this property of water,—of being attracted in this manner, and at that particular distance,—the most dreadful consequences would result to all mankind."

"Why, father!" said Rollo, in a tone of surprise; "what consequences?"

"I will tell you. But first I will tell you some of the smaller inconveniences we should have to bear, and then the more important

ones. One difficulty would be, that I could not write any more with ink."

"Why not?" said Rollo.

His father then dipped his spoon a little way into the tea, as he would have dipped a pen into the inkstand, and, taking it up, a little drop of tea hung at the tip of it, just like the ink in the pen. "There," said he, "you see that is the way I take up my ink. Now, if the ink was not attracted to the pen so, it would not come up; my pen would come out of the inkstand as dry as it went in."

"Would it?" said Rollo, with surprise. "But that is ink, and you were talking about water."

"Yes," said his father, "but it is just the same with ink. In fact, ink is only water colored very black."

"Could not you get *any* in your pen?" said Rollo, — "not any at all?"

"No," said his father; "unless it were attracted to the pen, it would not adhere to it at all. The pen would come out dry and clean, as it went in."

"Why," said Rollo, "how funny that would be! I should like to see such ink as that."

"That is the way it would operate," said

his father, "undoubtedly; and if you were to dip your fingers in it, it would be just so; they would come out clean and dry. In fact, if I should throw it over your face and clothes it would all fall off upon the ground, and leave you just as you were before."

"Why, father!" said Rollo; and he laughed outright at the idea of his father's throwing ink all over him, and especially of its falling off in that manner. In fact, it was hard for him to believe that it was possible for such a thing to be.

"I cannot show you any *ink* that will act so; but I can show you another liquid that will. There are some liquids that do not thus attract other substances; and if you dip things into them, they come out clean and dry.

"Are there, father?" said Rollo; "I never saw any."

"I will show you one," said his father, "after the tea things are moved away from the table."

QUESTIONS.

How did Rollo first attempt to dam up the open side of the trough? How did Jonas attempt it? How long did Jonas suppose the pleasure of sailing boats in the pond

would last? Why not longer? Was Jonas right or wrong in his expectations? What phenomenon attracted Rollo's attention? Did you ever notice this appearance? Did you ever think of inquiring into the reason of or nature of it? Did it ever appear to you to be anything remarkable? Do you think now it is anything remarkable? Whom did Rollo first ask about it? Did she know any thing about it? Did she know that she was ignorant? Whom did he apply to next? What did his mother say about it? Where was Rollo's father when he first asked him about the case? How did his father perform the experiment? What did he say was the name to the property of water which Rollo had observed? What is the difference between cohesion and adhesion? Was it cohesion or adhesion, strictly speaking, which Rollo had observed? Which is it which causes the drop to assume its round form? Which is it which causes the drop to remain suspended from the spoon? Are not both generally called cohesion?

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CHAPTER II

WATER.

VERY soon after this, they rose from the table, and Dorothy came in, and began to take away the waiter and the cloth. Rollo put his chair back, and then went to a table at the back side of the room, and dipped the pen into an inkstand that was there. He saw the ink adhering to the pen, and was satisfied that, unless it had been considerably attracted by the pen, it would all have fallen off, at once, back into the inkstand.

While he was looking at this, his father, who had before gone out of the room, came back with a small and very short glass phial in his hands, which he put down upon a corner of the table. Rollo went up to look at it. His father did not tell him not to touch it, as he knew he would not touch it without leave. His mother asked them to wait until she was ready to come in from the kitchen; and while she was gone, Rollo stood looking

at the phial. It seemed to be full of something which was of a kind of grayish color. He asked his father if he might take it up. His father said that he might lift it up once gently, and then put it down again. He took it up carefully, by the neck of the phial, and then immediately put it down, saying, "O, how heavy!"

In a short time, Rollo's father came to the table, bringing in his hand a saucer, a sheet of white paper, and a knitting needle; and, sitting down, he said that he was going to wait until Rollo's mother was ready. He also asked her to bring a tea-spoon with her, when she should come.

In a few minutes, she came with a tea-spoon; then Rollo's father took up the little phial, and said,

"This is *mercury* in this phial; or, as they call it sometimes, quicksilver." So he uncorked it, and poured it out into the saucer. It came out in a fine stream, like melted lead, and fell into the saucer as if it was very heavy.

"The reason that I have brought this out to you, Rollo," said his father, "is, that it differs from water in not having any apparent cohesion for most other substances

—so we can see, a little, by means of it, how water would appear, if water had done. Now, Rollo, go and get a pen, and dip it in, and see if you can take up a pen full as if it were ink.”

So Rollo went to the table, and brought a clean pen, and dipped the point into the mercury; but, instead of the mercury’s “jumping up,” as the water had done, the pen seemed to make a deep pit or depression all around itself in the mercury; and when he took the pen out, it was as dry as when it went in.

“Why, father,” said Rollo; “it don’t seem to like the pen.”

“No,” said his father, “it nkes itself better than it likes the pen. That is the difference between mercury and water. Water has the property of cohering, or adhering, pretty strongly to other substances; but mercury has the strongest attraction for itself. So, when you dip a pen into water, the water that is close around the pen, coheres more strongly to the pen than it does to the other water; and when you take the pen out, this small portion of water comes up with it. But when you put the pen into the mercury, the mercury that is close about the pen is more attracted

by the other mercury than it is by the pen. So it recedes from the pen; it shrinks away from it, as it were; and when you take the pen out, none of the mercury comes."

"Is that the way of it?" said Rollo.

"Yes," said his father; "and this simple difference in the cohesive properties of water and mercury, gives rise to great differences in the phenomena that the two liquids exhibit."

While Rollo's father was saying this, he observed that Rollo was dipping the pen in and out of the mercury, and was not paying much attention to what he was saying. In fact, what he was saying was rather too difficult for Rollo to understand, without attending pretty closely.

"Put the pen down a minute, Rollo," said his father, "and listen to me; and presently you may try experiments."

So Rollo put the pen down at once, and looked up at his father.

"I want to tell you what great differences there are between water and mercury, arising out of this fact, that water coheres to other things, and mercury does not. It follows from it that, if you dip

anything into water, the water rises around it, and spreads over its surface; and some water comes up with it, when you take it out. But if you dip anything in mercury the mercury is *depressed* around it, instead of being raised, and it does not come up with it at all, when you take it out. For the same reason, if you pour out a little water upon a table, it spreads around upon it, and you cannot take it up again. If you pour out a little mercury, on the other hand, it does not adhere to the table, but rolls about in little balls, and you can take it up clean with a spoon."

"O, let me try, father," said Rollo.

"Presently," replied his father. "Another different result is, that if you pour water upon anything that has small pores or interstices, like sponge, or cloth, or earth, it penetrates to every part, and coheres to every part, and keeps it all wet. But mercury would remain in a mass at the top, if the pores were very small; and if they were large enough to allow it to penetrate at all, it would all run off below, leaving the whole dry."

"How?" said Rollo.

"Why, if you were to make a little heap

of earth and gravel-stones, with a hollow place upon the top, and then pour water upon it, it would gradually soak in, as we call it; that is, it would diffuse itself all through the heap, and make it all wet. But if you were to pour *mercury* into the hollow, it would either remain there without going down at all, or else, if the spaces in the gravel were great enough to let it pass down, it would all run down together, entirely through, and would not cohere to the gravel at all."

"Where would it go to?" said Rollo.

"Down as low as it could get; and there you would find it, all together, or as much together as it could be."

Rollo's father then took up a little of the mercury with the tea-spoon, though it was difficult to do it; for it cohered to itself so strongly, and had so little attraction for the silver, that it seemed to be actually repelled. This, however, was owing to the fact, that the silver was not perfectly bright and clean. Rollo had been handling it, and, though it looked clean, it was really covered with a very thin and invisible film of moisture from his fingers, which kept the mercury from coming into

actual contact with the metal. At length, however, his father succeeded in taking up a small portion, and he then poured it out gently upon the sheet of paper; it rolled out like a sort of liquid ball. Rollo amused himself for some time in pushing it about, and dividing it into parts with the knitting needle. He observed that when he divided it into small parts, these parts were always round, like little balls; his father called them *globules*. When he brought two of these globules together, they would instantly unite into one ball, perfectly round and bright; unless it was a pretty large one, and then it was flattened a little at the top. His father explained to him that the reason why the mercury always took that form, was because the particles attracted each other strongly, and consequently they were all drawn in from every side towards the centre; and from this resulted the globular form.

“Father,” said Rollo, at length, “I think the reason why the mercury does not stick to the pen and to my fingers, like ink, is because it is so heavy. When you take the pen out, the mercury is so heavy that it falls directly back again.

"No," said his father, "that cannot be the reason, because that would not prevent its spreading out over the paper, or upon the table, and cohering to that. It is true it is a great deal heavier than water, but that does not occasion these different effects. It is the nature of the substance, in not cohering to other substances. Now, there are some things that *water* does not cohere to."

"Are there?" said Rollo; "what?"

"Oily substances, the feathers and fur of some animals, and some plants. Water rolls off from a cabbage leaf, just as mercury does from paper. So it does from feathers. A goose does not get wet by floating on the pond; and a duck's head comes up from the mud as bright and dry as it went down."

"Yes, I have seen it, father," said Rollo.

"And so with the furs of animals that live in the water."

"Yes," said Rollo, "Jonas says that he has seen a water rat come up out of water as dry as mother's muff."

"And then, again," continued his father "there are some substances that mercury *will* adhere to. For instance, if, instead of this sheet of paper, I had taken a sheet of

perfectly clean and bright *tin*, and put a globule of mercury upon it, it would have spread itself out upon it, and *wet* it, as it were, like water upon wood.

“But now, Rollo,” continued his father, “I must go. You may play with this mercury a little while, and then your mother will put it away for me.”

“Yes, but, father,” said Rollo, “you were going to tell me of some terrible consequences which would come from there being no cohesion.”

“Yes, — no cohesion between water and other substances,” said his father, rising, and standing by his chair, ready to go. “Well, I will tell you.

“First,” said he, “we could never write with pen and ink; for, if the water had no attraction for the pen, it would not come up from the inkstand; and then, if it had no attraction for the paper, it would not leave the pen and go to the paper when we move the pen along.”

“Yes, sir,” said Rollo, “you told me that before.”

“Then, secondly,” continued his father, “we could never wash any thing. Suppose, after you have been painting, some day, you

want to wash off the paint that is left upon the saucer. You dip it into water. The water adheres to the paint and to the saucer, and, when you rub it a little, the water and the paint move together, and fresh water poured on carries it all off. So, if the paint were upon a cloth, the water would penetrate among all the fibres of the cloth, and unite with the particles of paint there, and bring them out. But you could not wash anything out with mercury.

“Nor can you wash anything out with water, unless it is of such a nature that water has cohesion for it. For instance, you cannot wash out a spot of oil, because water and oil do not cohere. The water does not take hold of it, as it were. And so, if water had no cohesion for any thing but itself, nothing could be washed. Your hands would come out of it just as they went in. If it was poured upon clothes, it would all run off directly. You could not take it up with a sponge, nor wet anything with it whatever.

“But, in the third place, the worst consequence of all would be this. The water is retained in the ground by the attraction between it and the particles of earth. If it were not for this, it would not remain up near

the surface, but would all run down through the strata of earth to the lowest place it could get to, and leave the upper part of the ground entirely dry. After a heavy shower of rain, the earth would be as dry as before ; a great part of the water would run off in little dribbling streams, like a stream of mercury ; and the rest would go down through the ground at once, as a shower of shot would, through a heap of large stones. Of course all plants would die, the earth would be parched up, and men and animals famish. Were it not for this property of water to cohere to itself, and to adhere to other things, every plant and tree would wither and die for want of water in twenty-four hours, even if it was raining all the time."

"What ! if it rained all the time ?" said Rollo.

"Yes, every moment," said his father. "The rain would come down upon the plants and their roots, as this mercury would upon a quill top. It would roll off in globules, and not wet them at all."

Here Rollo's father began to move away, saying to Rollo that he had better observe carefully all the cases of cohesion that he might meet with, and that he would tell him

more about it some other time. He had, however, not gone far from the table before Rollo called him back, saying, in a voice of great interest and surprise,

“O father, father, see how bright your spoon is!”

His father turned round suddenly, and said, “Where?”

Rollo handed him the spoon. In the middle of the bowl, there was a large bright patch,—very bright indeed. He took it, looked at it a moment, and said, in a low tone, as if he was talking to himself,

“Why!—how foolish I was! How foolish I was!”

“What!” said Rollo. “What! What is it?”

“I might have known better than that,” said his father, still musing.

“What is it, father?” said Rollo, eagerly.

“Why, I might have known that the mercury would have united with the silver; but I did not think of it. You see, Rollo, that here is a spot that the mercury has ‘wet,’ as you call it. Silver is one of those substances that the mercury has an attraction for; and it has united with it, and I don’t know how we shall get it off.”

"However," he continued, "it will do to illustrate what I have been saying. If you put a little mercury upon this spot, you will find that it will cohere now, and will spread all over it, like water upon a board."

Rollo tried the experiment. He rolled a little globule of mercury into the spoon, and, the moment it touched the bright spot, it spread all over it at once; and, when he turned the spoon over again, it did not fall off. His father then rubbed it off as well as he could, but it only made the spot larger and brighter.

"Father," said Rollo, "I think you had better rub the mercury over all your spoons."

His father smiled, and said he would probably think differently when he should come to see it the next morning. But he gave Rollo a small piece of money which he told him he could brighten all over in the same way if he wished.

"Why not the spoon?" said Rollo.

"Why, to-morrow morning," said his father, "all this brilliancy will be gone, and the silver will look tarnished and dull."

"Then how can you get it bright again?" asked Rollo.

"I do not know," said his father; "I must ask some chemist."

It turned out that this was not necessary : for, in the morning, Rollo's mother rubbed the dull spot off, with a little whiting. But mercury ought to be used very carefully ; for, if the little globules get upon any thing that is of silver, as, for example, a spoon, a watch, a thimble, or a pencil-case, they immediately combine with the silver, producing spots which it is sometimes troublesome to remove. The kind of attraction, however, between the silver and the mercury, is thought by the philosophers to be of a different kind from that between water and glass, for example, although, in most respects, it is of a nature very similar

QUESTIONS.

What substance did Rollo's father bring to show to Rollo and his mother after tea ? In what sort of a vessel was it contained ? Why do you suppose it was necessary to have the phial short ? What was the first experiment which Rollo's father performed with the mercury ? What is the name by which mercury is commonly known ? What was the effect produced when a pen was dipped into it ? What did Rollo suppose was the reason why the mercury did not adhere to the pen or the fingers ? How did his father prove to him that this was not the reason ? What effect did the mercury produce upon the spoon ? Would it have produced any such effect if the spoon had been of glass ?

CHAPTER III.

THE THREE DIFFICULTIES.

THE next morning, Rollo was going across the yard towards the pump, carrying a paper boat, which he was going to sail in his sea, when Jonas met him.

"Ah, Jonas," said he, "you did some good by making that sea for me yesterday. I've learned all about water by means of it."

"What, *all* about water?" said Jonas.

"Why, — not quite *all*, perhaps; but all about cohesion, at any rate."

"Yes, I read about cohesion once in a book, and, if you have learned *all about it*, you have learned a great deal. However, boys generally learn all about a thing a great deal quicker, when they are as big as you, than when they grow older."

Rollo saw that Jonas said this with a sort of sly look; and in fact he had so often laughed at him for vanity and self-conceit, whenever he exhibited these foibles, that he knew now that he was really ridiculing his preten

sion to have understood completely a difficult philosophical subject so easily. He looked a little ashamed; but Jonas presently relieved him by saying that he was going to drive the cow to pasture, and asking Rollo to go with him, and tell him what he had learned by the way.

Rollo asked his mother's leave, and then they went along, Rollo having first put his paper boat down by the side of the pump. As they walked along, Jonas asked Rollo to tell him what he had learned about the attraction of cohesion; and so Rollo repeated, as well as he could, his father's conversation. He told him that the particles of water cohered to each other, and adhered to almost all other substances, whenever they came in contact with them. On the whole, he gave the substance of the information which he had received, pretty correctly; though, as usual with beginners in all studies, he spoke far too confidently, and made his assertions in too general and unlimited a manner.

"Very well," said Jonas; "I read something about it in a book once, and I should like to have you answer me some questions I thought of."

"Well, I will," said Rollo.

"If you can," said Jonas.

"O, I think I can," said Rollo, "for father explained it all to me, perfectly."

"The first question is the *dropping* question," said Jonas. "When I try to drop any medicine from a phial, after it gets a going, it drops well enough; but at first it won't run easily. It acts just as you say the mercury does. It keeps back in the phial, and heaps up at the edge, and does not want to go along over the glass."

"O, that is because the glass is dry," said Rollo, readily. "You must wet it with your finger, and then it will run. That is the way my mother does."

"Yes, but why don't it run of itself," rejoined Jonas, "and wet its own way? If there is an attraction between the glass and the water, why don't the water move right along over it?"

"I don't know," said Rollo, shaking his head seriously. "I mean to ask my father."

"The next question is the drying question. If you wet a piece of board, and then leave it a little while, when you come back, the water is all gone."

"Yes, it has dried up," said Rollo

"Yes, but it must have gone away somewhere," said Jonas.

"No," said Rollo, "it has dried up; it has not gone away."

"Why, yes," replied Jonas, "it must have gone away somewhere. You see, when I leave the board, the water is there; and when I come again, it is not there: of course it must be gone."

"It is all gone to nothing," said Rollo.

"Ho!" said Jonas, "I know better than that myself. I don't think you answer the second question any better than the first."

"Why, I don't see any question about it," said Rollo. "It hasn't anything to do with cohesion."

"Why, if there is an attraction between the water and the board, why doesn't it keep them together?"

Rollo insisted that the water all dried up "to nothing," as he termed it; and yet he was not very well satisfied with his explanation himself; but he was very unwilling to admit that he could not answer any of Jonas's questions.

"Well, what is the third question, Jonas?" said he.

"The third is about the water balls. I can

make water globules just like the mercury globules."

"Can you?" said Rollo; "on what?"

"On water itself."

"O Jonas!" said Rollo, with a tone of great incredulity.

"I can," said Jonas. "I have seen them a hundred times, when I was playing in the water. If you spatter the water when the sun shines on it so that you can see clearly, you will see little balls about as big as shot, rolling about in all directions, growing smaller and smaller, until they become only a little point, and then they vanish."

"They are bubbles," said Rollo.

"No," said Jonas; "there are little bubbles too, but they look very different from the water balls."

Rollo said that he wished Jonas would show him some, and Jonas promised to try and see if he could make them as soon as he should get back to the pump.

He did so, and he succeeded very well. Rollo saw the little globules very distinctly. They were different in their form from the bubbles; and then, besides, they rolled away very swiftly over the water, while the bubbles floated very slowly, or remained nearly at rest

"Now," said Jonas, "if the particles of water attract one another, why don't these little globules spread right out, at once, all over the surface?"

"Or sink in?" said Rollo.

"Yes," said Jonas.

"I don't know," said Rollo; and he terminated the discussion in the usual way, by saying, "I mean to ask my father." Jonas then went off to his work, and Rollo continued for some time at the pump, amusing himself with making these water globules. At length, he got tired, and his paper boat, after floating a short time, got gradually soaked through, and lay down upon her side, half submerged, like a vessel water-logged, as the sailors say. Rollo then went in the house to find his father.

His father had gone away; but he found his mother at work in the parlor. She called him to come and read to her; for, as Rollo did not go to school now, he used to read to his mother, and have some lessons besides, every day. After finishing the reading lesson, he concluded to propose Jonas's questions to his mother.

She heard them with a good deal of interest, and said she could not answer but one of them.

“Which is that?” said Rollo.

“The second,—the *drying* question, as you call it. Get your chair, and come and sit down here, and I will give you a little lecture upon evaporation.”

So Rollo got his chair, and took his seat opposite to his mother, and she began her lecture in the following words:—

“Your father explained to you that, when water is spilled upon wood, there is an attraction between the wood and the water, so that it adheres to the wood; and, in fact, that there is a similar attraction between water and almost all solid substances.”

“Yes, mother,” said Rollo.

“Now, there is another substance which also has a very peculiar attraction for water, and this attraction produces very singular effects,—very singular effects indeed.”

“What substance is it?” said Rollo.

“The air,” replied his mother.

“The air?”

“Yes, the air; which is all about us in the room, and out of doors. It is very thin; but you can feel it when you move your hand back and forth,—so.”

Here Rollo’s mother moved her hand back and forth rapidly, and Rollo did the same.

He could distinctly feel the impulse of the air upon his hand.

“Now, this air has a strong attraction for water, and when any water is lying upon a board, and the air is over it, the air gradually takes it up.”

“Takes it up? — why, how, mother?”

“It attracts it, and the particles of water rise up, one after the other, and mingle with the air, and float away.

“We cannot see them, for they are very small, and they rise very gradually; and they make no difference in the appearance of the air, when they have mingled with it. It is something like sugar dissolving in a cup of warm water. The water has an attraction for the sugar, and takes the particles off from it gradually, and floats them away, until all the sugar is diffused equally over the whole cup of water. So the air takes up the water. This is what we call *drying*. It is the water going off into the air, because the air has a stronger attraction for it than the solid substance it rests upon. But oil will not dry up in that way. If you pour oil upon a board, and leave it for months, when you come back, you will find it oily still. This is because there is a stronger attraction between the oil and the

board, than there is between the oil and the air."

"Will anything else evaporate besides water?" said Rollo.

"Let me think," said she. "There is oil,—that will not. What other liquids are there?"

"Milk," said Rollo.

"Milk contains a great deal of water; I believe a large part of its substance is of watery particles, and these will evaporate, leaving the rest. It is generally the case that when water has anything mixed with it, or dissolved in it, if you expose it to the air, the water will evaporate, and leave the other substances dry."

"There is ink," said Rollo.

"Yes," said his mother, "that is a very good example. It consists, you see, of a black coloring matter, dissolved in water; and the water will evaporate, and leave all the black part behind, on the paper."

"Then, it seems, nothing will dry up but water," said Rollo.

"I don't think of anything."

"Then I have learned one thing, haven't I?" said he.

"No, you have not learned yet that nothing

will evaporate but water, from such reasoning as this. It would be very poor induction."

"Induction?" said Rollo. "What is *induction*?"

"Why, when we say a thing is always true because it is true in all the cases we have known, that is induction."

"Is that a good argument?" said Rollo.

"Yes, sometimes; but we cannot establish a general truth in that way, unless we have taken a great deal of pains to get all the facts we can possibly collect. It would not be safe at all for us to judge from the very few liquids that we happen to think of just now. Boys are very apt to make false inductions."

"How?" said Rollo.

"O, in a thousand ways. Once I took you out in the fields to get some strawberries. I told you I knew a place where they were very thick and large. You went with me, and, as soon as we got into the field a little way, and you happened, for a few moments, at first, to find them few and small, you said, 'O mother, this isn't a good field at all.'"

"Was that false induction?" said Rollo.

"Yes: from a very few particulars, you came to a general conclusion, and your conclusion was wrong; for we afterwards found

them very large and very plentiful. To have made a sound induction, you ought to have waited till you had gone over the field in various directions ; and if you found them few and small wherever you went, then you might properly have supposed it to have been a poor field for strawberries."

"Why, then, mother, I should have *known* ; for I should have seen the field all over."

"No, you would, in fact, have actually *seen* only a small part of all the strawberries, and places for strawberries, in the whole field. But, after seeing a considerable part of it, you might, perhaps, have safely inferred that the rest would correspond. This would have been induction, that is, inferring a general conclusion from a knowledge of a small number of particulars."

"But I should not be perfectly sure."

"No, we can never be perfectly sure in induction, even when we are most careful and cautious, and therefore we must take great pains not to judge hastily. There is no way by which people make more mistakes than by coming to general conclusions from too small a number of facts. But we are getting away from evaporation. Let us see ; where did *we* leave off ?"

Rollo did not remember exactly, and so his mother began anew upon another part of the subject. It was very well that she did not allow him to come to the conclusion that no liquids could be evaporated except water, just because the few that he happened to think of could not; for there are several liquids, entirely different from water, which evaporate, and some of them more rapidly and readily than water itself.

QUESTIONS.

What was Rollo's boast when he saw Jonas? Did he really know all about water? Did he even know all about cohesion? Which do you think knew most about these subjects, Rollo or Jonas? What was the first question which Jonas proposed? What did Rollo say to this? What was the second question? What did Rollo say to this? Was he correct? What was the third question? Had Rollo ever observed these globules of water? How did Jonas know that they were not bubbles? Did he succeed in producing them, so as to show them to Rollo? How many of these questions did Rollo's mother undertake to answer? What was her explanation? Did they think of any other liquid besides water which would evaporate? What did she say about the evaporation of ink? Will oil evaporate? Are there any other liquids entirely different from water which will evaporate?

CHAPTER IV

EVAPORATION.

"THERE are several circumstances," said Rollo's mother, in continuing the conversation, "which make the air take up water faster than it otherwise would, or which *promote evaporation*, as the philosophers call it. One is warmth. If you warm a board or paper that is wet, or warm the air which lies over it, the moisture will evaporate much quicker. That is the reason why, when we want anything to dry quick, we hold it to the fire."

"Is it?" said Rollo.

"Yes," said his mother. "Air can only hold a certain quantity of moisture, though warm air can hold more than cold. So, if we want air to take up as much water as possible, and as fast as possible, we must warm it. Then, if we allow this warm air to take up as much water as it will hold, and afterwards cool it, there will be more in it than it will hold."

"And what becomes of the — the -- rest?"

"The surplus?" asked his mother.

"Yes, the surplus."

"Why, that falls down out of the air again in drops, — large or small drops. That is the way that it comes to rain. The warm air, in the long summer days, lies over the sea, and ponds, and rivers, and takes up water, as much, perhaps, or nearly as much, as the warm air can hold. This air then rises up where it is colder, or is moved in winds, off to the north, and thus gets cooled, and then it can no longer hold the moisture it contains; and so it falls down in drops of rain, or in hail, or in snow."

"Is that the way?" said Rollo.

"Yes," replied his mother. "There is a phenomenon which takes place in houses, in the winter, which is just like this, in principle. In the daytime, when the room is warm, the air takes up moisture from our breaths, and from various other sources, until it has more than *cold* air can contain. Then, in the night, the cold air, outside of the windows, cools the glass, and, through the glass, the air in the room which touches the glass; and so the moisture eaves the air, and at

taches itself to the glass, and makes the beautiful frost-work you have seen so often.

"So, with our breaths, in a cold, frosty morning," she continued, "the air which we breathe, when it comes up from the lungs, is warm, and takes up a great deal of moisture from all the passages which it comes through. Then, when it comes out into the cold, it is suddenly cooled, and cannot hold so much; and so the surplus becomes visible in little drops."

"Little drops?" said Rollo.

"Yes," said she. "That vapory appearance we see in a cold morning, like a little fog, is formed of little drops of water, too small for us to distinguish one by one, though all together they make a sort of haze. But it vanishes pretty quick."

"What makes the little drops vanish?" asked Rollo.

"Why, they spread about in the other air, and are redissolved; that is, the particles that compose them are taken up again by the air, and so they disappear."

"That's curious," said Rollo.

"I think it is very curious," said his mother.

“The evaporation of water is going on all the time,” she continued, “from all ponds, and lakes, and seas, and rivers—from the ground, the leaves of trees, the brooks—from all vessels of water, or watery liquids—and from all wet things, of every kind; and thus the air is continually receiving new supplies.

“Then there is another way by which water is turned into vapor, besides being taken up by the atmosphere; that is, by boiling it, and thus changing it into steam.”

“I have seen steam coming out of the nose of the tea-kettle,” said Rollo.

“What you saw is not strictly steam,” said his mother, “though it is commonly called so. Real steam is invisible.”

“Is it?” said Rollo.

“Yes,” said his mother. “If you heat water very hot indeed, it turns into a kind of hot, scalding *air*, which is called steam. This steam is, in fact, water, spread out, as it were, very thin, and pressing out in every direction, just like air, only it is all composed of particles of water; and as soon as you let it cool, it turns back to water again. So, you see, there are two ways of getting water off from an iron which is wet with it. The

first way is, to leave the iron out in the air and the air will gradually take all the water up, by its attraction for it ; and, if you warm the iron or the air a little, it will take it up all the faster. But the second way is, to put the iron over the fire, and heat it very hot indeed ; then the water will turn at once into steam, and it would go off from the iron whether there was any air over it or not. In fact, if there is a good deal of water, the steam will push the air away, and rise up in its place."

"And what becomes of the steam," said Rollo, "after it goes away from the iron?"

"Why, as soon as it should get away from the hot iron, and mix a little with the other air, it would cool, and turn into little drops of water again, which would make a little white cloud. That is the way when a tea-kettle is boiling. The fire below heats the bottom of the kettle so hot, that the water next to it turns into steam. This steam now is a great deal lighter than the water ; and so it rises up through it, in great bubbles. If the fire is very hot, these bubbles of steam come up very fast, and make the boiling noise that we hear. This bubbling and boiling is

because the fire is *under* the kettle, and, consequently, the bubbles of steam are formed at the bottom, and have to rise up through the water. If the heat were to come only upon the top of the water, I suppose there would be no bubbling; for the steam would be formed there, and would pass off at once, silently, without bubbling through the water at all.

“Now, when these bubbles come up to the upper part of the kettle, they fill the whole space above the water with steam; and, if you could peep in there, you would see that there was no cloudy appearance of vapor there; it would be pure and transparent, like air.”

“Did you ever peep in, mother?” said Rollo.

“No,” said she.

“Then how do you know, mother,” asked Rollo, “if you never looked?”

“Because I have seen water boiled in a glass flask; and then I could see through the sides of the flask, and it was all perfectly transparent and colorless; though, as soon as the steam came out of the top, into the cool air, it turned into a column of visible vapor. Besides, if you look into the nose of the tea

kettle you will see that there is no appearance of any cloudiness within; nor even without, until the steam has got away a little distance from the hot iron, so as to be cooled a little. You can see it, too, in chimneys, where wood is burning, or any other fuel which contains moisture. In a cold morning, a cloud of steam, as it is generally called, comes out from the top; but it does not begin to show itself until it has got up a foot or two above the top of the chimney; for it comes out so hot, that it must proceed a little way into the air to get cool enough to turn back into water again, or, as they call it, to be *condensed*.

“So, you see, there are two ways by which water may be carried off into the air. One is, by boiling it, and turning it into steam; and in this case it goes off in a mass, which is, in fact, all water, though it appears like air. The other way is, to let the air gradually take it up, by its attraction; and, in this case, it mingles with the air, and floats away. And when steam goes up into the air, it almost immediately becomes condensed into a cloud of very small, watery globules, and these are then gradually dissolved by the air

"If it were not for these modes by which water is carried up and diffused through the air, the world would soon be in a sad condition."

"Would it?" said Rollo.

"Yes. I think the consequences would be as dreadful as those your father said we should suffer if water were to be deprived of its adhesive and cohesive properties."

"What would the consequences be?" asked Rollo.

"Why, in the first place, if anything was once wet, we could never dry it."

"Couldn't we, possibly," said Rollo, "in any way?"

"It would be very difficult," said his mother. "It would be something as it is now with oil. If we get oil upon our clothes or hands, or upon a board, it is very difficult to get it out. The reason is, the atmosphere will not take it up. And we cannot easily contrive any way to remove it. If the air would not take up water, then, whenever we should wet our hands, they would have to remain wet. And every thing else which we might touch would be wet. There would be no such thing as drying anything."

“Then, again, the ground would be permanently wet and muddy. For, if the atmosphere had no attraction for water, all the water which is now in the atmosphere would fall at once, and flood the ground. A great part of this would run off into the rivers and into the sea; but enough would be retained by the attraction of cohesion to make everything wet and disagreeable. It would be as if it should rain oil until everything was drenched with it; and then a large portion might run off, but still it would leave everything soaked with oil, never more to be dry.

“And then we could never have any more rain. For after the water, which is now in the atmosphere, had fallen down, no more could ever get up; and, of course, we should never have any more clouds or rain. The streams, of every kind, would soon all run off in the sea, leaving their bottoms forever muddy; and then everything would continue wet, wet everywhere and perpetually. So you see, Rollo, how nicely the properties of water have been arranged to make this world a pleasant place for us to live in.”

Here Rollo's mother put away her work, and said that she could not talk with him any

longer; and he went out to find Jonas, to tell him what he had learned in answer to his second question.

Rollo met Jonas going into the garden to his work, and Jonas asked him to go out with him, for he wanted to talk with him a little. While Jonas was at his work hoeing, he told Rollo that he had thought of an experiment to prove to him that water does not all dry up "to nothing," as Rollo had thought.

"O, I know it does not, now," said Rollo; "mother has explained it to me. It goes off into the air, in very fine, invisible particles. But what was your experiment?"

"Will you try it," said Jonas, "if I will explain it to you?"

"Yes," said Rollo, "if I can."

"Very well; first you must go into the house, and get a phial."

"What kind of a phial?" said Rollo.

"O, any kind of small phial; you had better get one out of the medicine closet, that is about empty, and ought to be washed out, and carry it to the pump, and wash it out clean, and then bring it to me."

So Rollo went, and asked his mother to give him such a phial; and she did so. Rol-

lo brought it to the pump, and tried to pump water into it, but the water would not go in. It poured down in torrents all over the sides of it, but very little would go in. He, however, at length succeeded in getting in as much as was necessary for washing out the phial; then he carried it to Jonas, to ask him what the experiment was.

Jonas took the phial into his hands, and examined it.

"There, you see," said he, "there are some drops of water on the inside of the glass, and some on the outside. Now, put the cork in, and go and put the phial down in the sun. Then, in about an hour, go and look at it again. Now, if the warmth of the sun makes the water go all 'to nothing,' the glass will be dry, inside and out; but if the water all *goes away*, when it dries up, then the outside will dry, but the inside will not, for the water that is inside cannot get away."

"Yes," said Rollo, "that will prove it. I will go and put it in a good place."

Rollo accordingly put it in a corner of the yard where the sun shone very warm, and then went away to play. He did not think of the phial again until the next morning

and then, when he and Jonas went to look at it, they found that it was perfectly dry outside, but inside there was a sort of dew upon the glass, and some drops of water in the bottom. So they considered it established that water, in drying up, did not go "all to nothing."

QUESTIONS.

What is the meaning of the expression "promote evaporation"? What is it that Rollo's mother said did promote evaporation? Which can hold the greatest quantity of water, warm air or cold? When warm air has taken up all that it can, and afterwards becomes cold, what happens? Is true steam visible or invisible? Is not what is often called steam visible? How does it look? What does it really consist of? What proof did Rollo's mother offer that true steam was not visible? What would be some of the consequences if water did not possess the property of being dissolved by the air? What was Jonas's experiment? What did he intend to prove by it? Did it succeed to Rollo's satisfaction?

CHAPTER V

DAM BUILDING.

ONE day, Rollo's cousin James came to see him, and he and Rollo concluded to go down into the woods behind the house to play. They came to the great brook, and amused themselves for some time in looking into the deep places, to see if they could find any fishes.

It was midsummer, and the brook was very low. Rollo said that he wished that there was as much water in the brook as there had been early in the spring.

"*Then, James,*" said he, "it was almost full, up even with the banks; but now there is only a little stream running over the pebble stones from one deep place to another."

"Let us build a dam, then," said James; "that will make it deep."

"O, so we will," said Rollo. "We can build it of sods. We will go up and get my little spade to cut some sods with."

So the boys sauntered along home to get the spade. They found it in its place, for Rollo was always very careful to put it where it belonged. James saw Rollo's little wheelbarrow in the shed while Rollo was getting his spade, and he proposed that they should take that down too. "Because," said he, "you know, Rollo, we may want to bring our sods some distance."

So the boys put the spade into the wheelbarrow, and trundled it down to the brook. They moved so slowly, and stopped so often to talk about what they saw by the side of the path, that it was nearly half an hour before they got back to the brook; and then, just as they were beginning to dig their first sod, they heard a noise like some one calling out to oxen, in the woods beyond them.

"What is that?" said James.

"O, it is only Jonas," said Rollo.

"I wish he would come here," said James, "and just show us how to build our dam."

"He is coming right along here," replied Rollo; "see, there is where he crosses the brook."

So saying, Rollo pointed down a little below them, and James saw a smooth, shallow

place in the brook, where the bottom consisted of sand and gravel, and a cart path led down into it from the bank on both sides.

"That is Jonas's ford," said Rollo.

"Ford?" said James; "what is a ford?"

"O, it is such a place as that, where horses and teams can walk across a brook. Only in rivers, at a ford, the water is a great deal deeper. Jonas went across a ford on a horse once, where the water was up so high that he had to lift up his feet to keep them out of it."

"O Rollo!" said James, incredulously.

"He did," said Rollo. "He told me so. But this ford is very shallow, — though it is pretty deep in the spring, when the water is high. Jonas made the ford on purpose for his cart to go through."

By this time, the horns of Jonas's oxen, and presently Jonas himself, and a cart, loaded with small sticks of wood, began to appear through the bushes. The cattle came down to the ford, and stopped upon the sandy bed of the brook to drink. Jonas walked over the brook upon a log which he had drawn across it just above the ford, for a bridge. He left the oxen in the brook, and



"THAT IS JONAS'S FORD," SAID ROLLO. Page 63.



walked up the bank to where Rollo and James were at work, and asked them what they were doing.

"O, we are building a dam," said Rollo.

Jonas smiled.

"Now, what are you laughing at, Jonas?" said Rollo.

"Why, nothing, — only your dams and bridges are very apt to go down stream."

"But this will not," said James, "for we are going to make it of sods, — good, heavy sods."

The boys had some further conversation on the subject; and at length Rollo said that one reason why he was going to build a dam, was to make an experiment on the philosophy of water. He said that his mother had given him a book where he had read something about running water, and now he was going to try some experiments.

"There will be two conflicting principles, you see, Jonas," said Rollo, very gravely, repeating what he remembered to have read in his book. "First, the gravitation of the water, tending to carry it down; and, secondly, the resistance of the dam, tending to keep it back."

Just at this time the boys heard a rustling among the dry leaves near them, and, looking up, they saw a young lady coming along a path under some trees, towards them. It was Miss Mary, their old school-teacher.

Miss Mary paused a moment upon the bank, and then said, —

“There are two other conflicting principles, that I think it more likely you will illustrate,” said she.

“What are they?” said Rollo.

“Why, the first,” rejoined Miss Mary, “is the desire of all boys to play in mud and water; and, secondly, the desire of all mothers to keep them away from it.”

“O Miss Mary,” said James, “there is not any mud.”

“No,” said Rollo, — “only water, — and clean sand and gravel. Besides, I am very careful not to get wet and muddy about the brook. See!”

So Rollo pointed down to his shoes, and Miss Mary saw that they were clean and dry. In fact, Rollo and James both had more sense than most boys have, in respect to playing in the water, as they always took special pains to prevent getting their shoes or clothes wet

and muddy ; for Rollo had observed that this always gave his mother a great deal of trouble, and prevented her allowing him to go near the water the next time.

After some further conversation, Jonas said that the neatest way to make their dam was to make it of a wide board, just long enough to reach from bank to bank ; and he explained to them fully how to do it, supporting it with stakes on the lower side, and drawing gravel against the lower edge and the ends of the board, upon the upper side, to make it tight.

“ And where shall we get our board ? ” said Rollo.

“ I will get one out for you at the house, when I go up,” said Jonas.

“ And bring it down with you on the cart ? ” asked Rollo.

“ Yes,” said Jonas. “ And you and James may ride up, too, if you wish.”

“ Well ! ” said Rollo and James, with a tone of great satisfaction ; and they laid down their spade, and ran towards the ford, and across the log, so as to get into the cart ; for, as the oxen were standing in the brook, the tail of the cart was so near the farther

bank that they could climb in. It was not large load of wood, and Rollo and James clambered up to the top of it.

"We shall have a ride through the brook," said James.

"Yes," said Rollo; "and see Jonas. He's measuring."

James looked, and saw that Jonas was measuring the breadth of the brook from bank to bank, at the place where they were going to make their dam. These banks were about a foot and a half high, and were nearly perpendicular, and formed of a sort of green moss, which covered and concealed the earth. Jonas measured from one of these banks to the other, with his goad stick, so that he might make the board of the right length.

Then he came down to the ford, and spoke to his oxen, and they, obedient to his command, began slowly to move up the slope, which led from the bed of the brook where they had been standing. Rollo and James sat on the top, upon the wood. As they rode slowly along the cart road, towards the house, they saw Miss Mary just disappearing by a narrow footpath which led through the

thicket in another direction. Rollo called out to her to come back by and by, and see their dam. Miss Mary said that she would, and that, if it worked well, she would give them a lecture upon philosophy, by the help of it.

When they reached the house, Jonas threw off his load of wood, and then went with the boys to find a board. He took a pretty wide one from a pile of boards and other lumber which was in a corner of the yard, and, after carefully measuring a certain portion of it with his goad stick, he sawed it off, and then took it under his arm, and carried it to the cart. He then went off towards the barn.

"Where now, Jonas?" asked Rollo.

"I am going after an auger," said Jonas.

"An auger," exclaimed Rollo, "what is that for?"

"You'll see," said Jonas.

Presently Jonas appeared again, coming out of the tool-room door, with two augers in his hand. He came to the board, and began to bore a hole with the large auger very near the middle of it.

“Why, Jonas,” said James, “you’ll spoil the dam. That hole will let the water all run through.”

“But I’m going to make a plug to stop it up,” said Jonas.

“O,” said James.

“Seems to me that is not very wise,” said Rollo — “to make a hole, just for the sake of making a plug to stop it up with.”

Jonas said nothing, but went on boring his hole. After he had finished it, he took the small auger, and bored two small holes with it by the side of the great one. These two small holes were bored in such a way that, when the board was afterwards placed upright upon its edge across the bed of the brook, one of them was directly over the other, — the lower one being pretty near the lower edge of the board, and the upper one near the upper edge. He also made three plugs to fit the three holes.

Jonas then put the two augers away, and went and made two strong stakes. Then he put the board, and the stakes, and the axe, into the cart, and told the boys to climb in. This the boys were very ready to do. Jonas then took his seat upon the tongue, before

the cart body, and they all rode off towards the brook together.

When Jonas came to lay the board across the brook from one bank to the other, Rollo exclaimed, —

“There now, Jonas, you have got it too long; I thought it was too long.”

The board did, in fact, extend a few inches over upon the green, mossy bank on each side. Jonas, however, took the spade, and cut a little notch or groove in each bank, where the ends of the board were to come, and then crowded the board down into them. Thus the board extended into the bank a little on each side, and this held it pretty firmly in its place. Then Rollo saw that Jonas had not made a mistake in his measure.

To confine the board still more securely in its position, Jonas next drove down the two stakes behind it, into the bottom of the brook, — one near each end. Then, with Rollo's little spade, he dug a little trench in the sand and gravel, exactly under the lower edge of the board, so as to let the edge go down a little below the surface of the sand and gravel. When this was done, he drove the board down into it, striking it gently

upon the upper edge, in several places, so as to settle it all together. When it was settled down well into its place, he put the axe upon his shoulder, and said, —

“There, boys, now take your spade, and bank it up well with gravel on the upper side, and see if it will hold water.”

“How much must we bank it up?” said Rollo, calling after Jonas, as the cattle were just going through the ford.

“O, the more the better,” said Jonas. “If you don’t bank it up well, it will *blow*.”

“What does he mean by *blow*?” said James.

“I don’t know,” said Rollo. “I’ll call out and ask him. — Jonas! Jonas! what do you mean by *blow*?”

But Jonas was too far gone for Rollo to get any answer. When he listened for a reply, he could hear nothing but the distant sound of the heavy cart wheels upon the dry brush, and Jonas’s voice calling out to direct the oxen.

When Rollo and James turned to their dam, they found that the water was slowly accumulating upon the upper side of it.

“O, look,” said Rollo; “the water is dam-

ming up! it is damming up! We must shovel the gravel on quick."

So Rollo stepped down upon a dry sand-bank just above the dam, and began throwing sand, and gravel, and mud, from the bottom, over towards the board. He threw it against the ends of the board, and along the lower edge, so as to stop the joints, as he called them. James stood by, looking on, and wishing that he had a spade too. Presently, however, Rollo stopped to rest and let James take his place; and while they were working busily so, Miss Mary, returning from her walk, came back to the place to see how they got along.

Miss Mary told James that his feet were getting wet; and James, on looking down, saw that the water was rising over the sand-bank, and spreading all around his feet. So James jumped off of it to the shore, and said that then they could not shovel on any more gravel.

"If you had a hoe," said Miss Mary, "you could stand down below the dam, and hoe it on; for you could reach with your hoe down to the bottom of the water."

"Well," said Rollo, "let us go, James

and get some hoes, and bank it up a great deal; for we don't want our dam to blow."

"To *blow*," said Miss Mary; "what do you mean by that?"

"Why, I don't know, exactly," said Rollo; "only Jonas said that, unless we banked it up pretty well, it would blow."

"I presume he meant that it would leak," said Miss Mary.

This was a pretty good conjecture at the meaning of the word, but it was not exactly correct. The children did not find out till afterwards what it was that Jonas meant.

Miss Mary told them that it was better to make their work secure, and accordingly Rollo went up to the house, and brought down two hoes, one for himself and one for James. They then put some large pieces of decayed logs, which they found in the woods pretty near, in the bed of the brook below the dam, to make a dry place to stand upon. Then, standing there, they reached over the board, and drew the sand and gravel from the bed of the brook above it towards the dam, until they had banked it up very nearly as high as the top of the board. In the mean time, the water was continually rising, until

at length, it got pretty deep, — so deep, in fact, that they could not draw up any more gravel.

“There,” said Rollo, “it makes a very pretty little pond.”

“Yes,” said Miss Mary, “only the water is very muddy.”

“O, that is only because we hoed the sand and gravel with our hoes,” said Rollo. “It will soon settle.”

The children sat down upon the bank to watch the rising of the water, and to see if it would not become more clear; but it did not become clear very fast, and there was a sort of scum of dust, leaves, straws, and other light substances, which the water had taken up from the surface of the ground, which it gradually covered, as it had risen higher and higher, and had consequently spread out over places which before were dry.

At length Rollo, as if suddenly recollecting himself, said, —

“O Miss Mary, you promised to deliver us a lecture.”

“Well,” said Miss Mary, “I will begin now.”

So Rollo and James sat still and listened attentively while Miss Mary commenced her lecture, as follows.

QUESTIONS.

What was the state of the brook when Rollo and James went down to see it? What season of the year was it? Why are brooks higher in spring than in midsummer? What is a *ford*? Did Jonas have much confidence that they could build a dam that would stand? What difficulty did he seem to anticipate? What difficulty did Miss Mary seem to anticipate? What preparatory step did Jonas take before he left the brook? Did he saw off the board so as to have it exactly as long as the brook was wide? Why did he make it a little longer? How many holes did he bore? How were the holes placed, in respect to each other? What was the appearance of the little pond of water, when it was completed?

CHAPTER VI.

HYDRAULICS.

“WATER is a *fluid*. It is called a *fluid* because the parts of it move very easily among themselves. All substances are fluids if their parts move easily among themselves. So milk is a fluid, and vinegar is a fluid, and air is a fluid. But wood is not a fluid, for the parts or particles of wood do not move easily among themselves. In fact, you cannot move them among themselves at all.”

“Why, you can break the wood,” said Rollo.

“Yes,” replied Miss Mary, “but that is not moving the particles *among themselves*;—it is separating the particles, dividing them moving one part away from another, but not moving them among themselves. Now you may answer some questions.

“Is iron a fluid?”

“No,” replied Rollo and James together.

“Is brass?”

"No."

"Is sponge?"

"Yes, a little," said James.

At the same instant that James was saying yes, Rollo was just going to say no; but he was not quite sure.

"No," said Miss Mary, "sponge is not fluid at all. True, you can press the parts together, and then they will spread open again; but they do not move at all among themselves. But there *are* substances which are a little fluid."

"What?" said Rollo.

"Pitch, and lava from burning mountains, and candy before it is cold. The particles of all these will move about among themselves, though with difficulty; and so they are called semi-fluids, that is, half fluids; for *semi* means *half*. But water is a perfect fluid; for the particles not only move among themselves, but they move easily. Do you understand all that?"

"Yes," said the boys, "all that is very plain."

"Now," continued Miss Mary, "a fluid has ~~severa~~. very remarkable properties."

“Properties?” said Rollo; “what are properties?”

“I know,” said James; “houses and land is property.”

Here Rollo laughed loud and long at James’s idea that water or any other fluid could have property in such a sense as that; even Miss Mary smiled a little, and said that she did not mean property in that sense.

“Well, what kind of property, then?”

“*Properties*, I said,” replied Miss Mary.

“That means—I hardly know how I can explain it to you, now. Properties are,—are—I think, now, the best way will be to tell you what some of the properties of a fluid are, and then you will see for yourself what the word means.”

“O, I remember, now,” said Rollo; “father explained it to me once.”

“The first property of a fluid,” continued Miss Mary, without replying to Rollo, “is that, if it is left to itself, the surface of it becomes level.”

“Always?” asked Rollo.

“Yes, always, I believe,” continued Miss Mary. “The surface or top of the water in a bowl will always be exactly level, so that, if

the bowl were to stand still, and the water freeze, a ball would not roll upon it one way any easier than another. So the water in a pond, when it is still, will always be exactly level. And the water in the sea will be level except when the wind, or some other cause, disturbs it. Now, the reason why it is so, is this: As the particles of water move very easily among themselves, if one part of the water should, by any accident, be higher than the rest, it would move and settle away by its weight towards the lower part, and thus make it level again. And so, you see, one of the properties of a fluid is, that its surface is always level, when it is left to itself."

"Is that what you mean by property?" said James.

"Yes," answered Miss Mary. "The surface in brooks and rivers is not level, because water is continually coming in, at one extremity, from the springs among the mountains, and going out, at the other, into the sea, which is lower; so that the water, throughout the whole course of the stream is always moving, seeking its level. The nearer level it is in any part of its course, the slower it moves; and the steeper the descent

is, the swifter it goes. Consequently, whenever you see the water smooth and pretty nearly still, as it is in your dam, then you may know that the surface is pretty nearly level. But if it shoots along swiftly, then you may know that the surface descends."

"Another property of fluids," continued Miss Mary, "is, that they press in all directions."

"What do you mean by that?" said James.

"Why, if you had a barrel full of water here, the water would press not only on the bottom of the barrel, but upon the sides; and so, if you were to bore a hole any where, the water would spout out. But if you had a mass of iron or of wood of the shape of the barrel, that would not press anywhere but downwards, upon the floor, or upon the ground, whichever it might stand upon. It would press very heavily upon the floor, or the ground, but it would not press outwards at the sides at all. What made me think of this principle," continued Miss Mary, "was the sight of your plugs."

"How did that make you think of it?" said Rollo.

"Why, the water in your dam," continued Miss Mary, "not only presses with all its weight upon the sand and gravel on the bottom, but it also presses outwards, against the dam; so that, if you pull out the plug, the water will spout out."

"O yes," said Rollo; "I knew that before."

"The reason," continued Miss Mary, "why water presses outwards as well as downwards, is, that the particles can move easily in all directions; and so the water which is down near the bottom of your dam, being pressed by the weight of the water which is above it, is pressed *downwards*; but, then, if it cannot move downwards, on account of the solid bottom of sand and gravel, it will slip out to one side, whenever it can find an opening. This, you see, is because the particles can easily move among themselves. But the particles of stone, near the bottom of a large mass of stone, can only press directly downwards; for they do not move easily among themselves, and so cannot move out of the way."

"I mean to go and pull my plug out," said Rollo.

"Well," said James; and the two boys started together to go down to the dam.

"Pull out the big plug," said James.

"No," said Rollo; "the little ones first, and then the big one."

"Stop a minute," said Miss Mary.

The boys paused, and looked up towards Miss Mary. James was standing upon the bank, and Rollo stood below the dam, with his hand upon one of the plugs.

"How many little plugs are there?" she asked.

"Two," said Rollo.

"And one is higher up than the other."

"Yes," said Rollo, "right over it; see;" and he pointed to the two plugs, so that Miss Mary could see them.

"Now," said Miss Mary, "if you pull out the upper plug, the water will not spout out so far, because it is not pressed so hard by the water above it."

"Why not?" asked Rollo.

"Because," said Miss Mary, "there is not so *much* water above it. It is not so far below the surface. I want you to understand exactly the reason why the water will come out; so take a little stick and run it down

into the water, above the dam, until you get it exactly opposite to the end of the plug."

Rollo did so.

"There," said he, "I have done it exactly."

"Well, now the water that is down as low as the end of the stick, is pressed by all the water that is above it, up to the surface, and, as it can move off one way as easily as another, wherever there is an opening, the moment you take out the plug, it will at once be crowded directly out of the hole."

"Yes," said James, "I understand. Now, Rollo, pull it out."

"Well, out with it," said Miss Mary.

So Rollo pulled out the plug, and the water came spouting out after it, just as they had all expected. It was projected a foot or more from the dam, and struck the sand below, and then ran off into the old channel; which had, however, now become almost dry, on account of the water having been stopped by the dam.

"Now," said Miss Mary, "put in the plug again a little."

Rollo did so, and then looked up to Miss Mary to see what he was to do next.

"Now," said she, "put your stick into the water as you did before ; only this time run it down until it is opposite the lower hole."

Rollo tried to do so ; but he could not find the end of the lower plug very well, because it was concealed by the sand and gravel which he and James had hoed on. He, however, pushed the sand away a little, and soon found it.

"It is a good deal deeper, isn't it?" asked Miss Mary.

"Yes," said Rollo, "half a foot."

"Then," said Miss Mary, "there will be half a foot more of water above it pressing it *down*, and ready to press it *out*, as soon as you take the plug out, and give it an opening. Of course it will spout out farther. Pull it out, and let us see."

So Rollo pulled out the lower plug, and the water spouted away a great deal farther than it had done from the upper hole. Then he asked Miss Mary to let him pull out the upper plug too, and let both of them spout together.

"And so have two jets at the same time," said Miss Mary.

"Yes," said Rollo. "Are they *jets*?"

"Yes," replied Miss Mary, "streams of water spouting out of a small opening like that, are called *jets*."

"Shall I pull it out?" said Rollo.

"Yes," replied Miss Mary, "and the big one too."

So Rollo pulled them all out; and he and James stood upon the bank very much delighted to see the three jets of water. The large hole was about as low down as the lowest of the small ones, and of course it had as much weight pressing down upon the water which came out of it, and of course the water was forced out just as far. Miss Mary called upon the boys to observe that fact.

"The principle is," said Miss Mary, "that the pressure is always the same, at the same depth, and ——"

"O James," interrupted Rollo, "see how it spouts!"

"And so, whether the hole is large or small ——"

"Look! look!" said James; "see what a hole it is digging into the sand!"

Miss Mary found that it was vain to expect them to pay much attention to her ex-

planations while such water-works were playing before them; and she might have consoled herself by reflecting that far more distinguished lecturers than herself often find their experiments more attractive than their theories.

She did not, therefore, attempt to philosophize any more, but went down close to the bank, where she could see more distinctly, and watched the water from the jets as it plunged into a sort of basin, which it soon formed in the sand below, and then ran off, happy in its release, to fill the channels which had become, by the stoppage of the water above, nothing but a succession of little stagnant pools.

At last she said that it was time for her to go home, and Rollo and James concluded that they would go too. So they walked along towards home together. Before they left the dam, however, they put the three plugs in again safely, because, as Rollo said, he wanted to have the dam brimming full when he should come down to see it the next morning.

QUESTIONS.

What was Miss Mary's definition of a fluid? Is brass a fluid? Is sponge? Did either of the boys think that sponge was a fluid? Why, probably, did he think so? What is a semi-fluid? What examples did Miss Mary give of a semi-fluid? What example did Miss Mary give to illustrate the meaning of the word *property*? Did Rollo at first remember the explanation which his father had given him before of this word? What was the second property of water which Miss Mary mentioned? What led her to think of it? Did Miss Mary expect that the water would spout out more forcibly from one of the holes than from another? Which one? Why? What name did she give to the streams of water spouting out from the holes in the board?

CHAPTER VII

THE MEASURE OF PRESSURE.

WHEN Rollo got home, he found that his father had not yet come, and that supper was not quite ready; and so he thought he would go and meet his father. He accordingly took his hoop, and ran out of the gate into the road, hoping that he might overtake James, who, he supposed, could not have gone very far.

He did not overtake him, for James had left the main road to go home by a cross path, through the woods and fields. So Rollo went on alone, trundling his hoop, until he came to a bridge which led over a brook, which the road had to cross. He stopped here, and leaned over the railing of the bridge, to look down into the water.

It was a large brook, and there was a mill upon it, at a little distance below. There was a dam at the mill. There is always a

dam where there is a mill upon a stream of water, to keep back the water, and make it rise high in the pond above the dam. The pond above this mill-dam extended back nearly to the bridge, so that the water under the bridge was not a rapid stream, tumbling and foaming along; but it was deep and almost still.

“Now,” said Rollo to himself, “I can tell whether the water is level. I’ll throw a stick in.”

His idea was, that, if the water was level, there would be no current; but that, if there was any current, so as to float the stick slowly down under the bridge, then there would be a current made by the water’s seeking its level.

So he threw in a little stick. At first, it floated a little way up the stream, being driven by the impulse which he had given it, in throwing it. But it moved more and more slowly, as its *momentum* — that is, the force with which it was moving — was gradually extinguished by the resistance of the water, and then it began slowly to move the other way. Rollo observed also several little



"WHAT ARE YOU SPECULATING UPON NOW?"—Page 97.

bubbles, and one or two dried leaves, all coming down in the same direction towards the bridge.

"Yes," said he, "there is a current."

Just at that moment his father came along. Rollo did not observe him until he had got very near him.

"Well, Rollo," said his father, "and what are you speculating upon now?"

"Why, father," said Rollo, "you see this water?"

"Yes," said his father.

"Well, does not it look as if the surface of it was level?"

"Yes, it does appear sensibly level."

"What do you mean by *sensibly* level?" said Rollo. "I don't see that water can be sensible at all."

"I did not say it was sensible," rejoined his father, "but sensibly level,—which means level so far as can be perceived by the senses, that is, by seeing or feeling. This water is sensibly level; that is, I do not see that one part is any higher than another, and yet we know that moving water never can be level; for the difference of level is all that makes it move."

"Well, father, is not a pond level?" said Rollo.

"No," said his father, "not generally."

"O father!" said Rollo, with surprise; "I thought that still water was always perfectly level."

"What made you think so?"

"Miss Mary told us so."

"Very well; she was correct. But suppose I had said that a pond *was* level, — what then?"

"Why, I was going to say," replied Rollo, "that there might be a little brook come into it at one end, and run through it, and out at the other end; and so the water might move along through the pond, while yet it was level."

"No," said his father; "for it is only still ponds that are level, not ponds which have brooks running through them. Because, if a brook were to run in at one end, the water would accumulate and rise at that end, and so that end would become the highest. Then the water at that end, being raised a little higher than at the other, though not sensibly higher, would press and settle away towards the other end; but, as fast as it settled

away, more would come in from the brook, and as fast as it moved towards the other end, it would flow out through the outlet."

"Yes, father," said Rollo, "I see."

"And so it is with ponds as with all other water; where there is a current, we may be sure that the surface is not level."

"So that I could skate easier one way than the other," said Rollo.

"There would not be any sensible difference," said his father.

While they had been holding this conversation, Rollo and his father had been walking along slowly; and now they had reached home. Rollo's father told him that he would tell him something more about the subject after supper.

Accordingly, after supper, when Mr. Holiday had taken his seat by a window which opened towards the setting sun, Rollo came and asked him to tell him then. Rollo took his seat in a little rocking-chair by his father's side.

"In speaking of the pressure of water," said his father, "there is one word which is used a great deal, and which it is important that you should understand."

"Well, sir," said Rollo, "and what word is it?"

"*Column*," answered his father.

"Column?" said Rollo. "I believe I know what *column* means."

"What does it mean?" said his father.

"Why, — it means, — I can't tell exactly; but it is something about a building."

"Yes, a tall pillar, in building, is called a column. A column of water is much the same in form. Suppose there were a dollar lying flat upon the bottom of a tub of water. Now, all the water which would be exactly above this dollar, from the dollar itself up to the surface of the water, would be called a column. You see it would be of the form of a column or pillar in building."

"Yes, sir," said Rollo.

"Now, if there were a hole in the bottom of the tub, just of the size of the dollar, and the dollar were to be fitted into it exactly, and then the tub filled with water, the dollar would have resting upon it only the weight of that column of water which was exactly over it."

"Yes, sir," said Rollo.

"Because, you see," added his father,

“that the rest of the water would rest upon the other parts of the bottom of the tub. By this plan you can calculate how great the pressure will be upon any part of the bottom of a tub, for it will always be just as great as the weight of a column of water as large as the part, and as high as up to the surface of the water.

“And it is just so,” continued his father, “upon the side, because water presses sideways just as much as it does downwards.”

“Yes, sir,” said Rollo; “Miss Mary explained that to us. She said it was because the water moved so easily.”

“Yes,” added his father; “the particles move easily among themselves, and so transmit motion and pressure in every direction.”

Rollo did not understand exactly what his father meant by transmitting motion and pressure; but he did not ask for an explanation, and so his father went on.

“Therefore, if the hole which the dollar is made to fit into, is in the side, the pressure of the water upon it would be exactly the same with the pressure upon it when it is on the bottom, were it not for one circumstance.”

“What is that?” said Rollo.

“Why, the hole being upon the *side*, is cannot be down so low as if it were upon the bottom. Only the lower edge could be as low as the bottom, and just along this lower edge the water would press as hard upon the opening in the side, as it would upon an opening in the bottom. But the upper part of the hole would be nearer the surface, and of course would not be pressed so hard.

“Therefore,” continued Rollo’s father, “if we wish to know how great the pressure of the water would be upon any space in the *side* of the vessel, we must take the middle of the space as the average depth from the surface, and then the pressure upon it will be as great as the weight of a column of water as large round as the space is, and as high as it is from the centre of the space to the surface of the water. Do you understand this?”

“Why, — *pretty* well,” said Rollo.

“Not perfectly well?” inquired his father,

“Why, not quite so well as what Miss Mary explained to us.”

His father laughed, and said, “I suppose I

am not quite so good a lecturer as Miss Mary is. But when did she tell you anything about this?"

"This afternoon," answered Rollo, "down by our dam."

"Your dam?" said his father. "I did not know that you had any dam."

"Yes, sir," said Rollo; and he explained to his father how they had made a dam, under Jonas's directions, and how Miss Mary had made use of it as a piece of apparatus, illustrative of the doctrines of hydraulics.

"And there!" continued Rollo, "I promised to go and tell Jonas how our dam succeeded; and I must go now."

"Wait a minute," said his father; "let me first question you a little upon what I have been explaining to you. Suppose that a tub of water were to be suspended in such a way that you could get at the bottom of it, and a hole were made in the bottom as large as you could cover with the palm of your hand; now, if you were to put your hand there, and attempt to keep the water from coming out, how much weight should you have to support?"

"I don't know, sir," said Rollo.

"I do not mean how much the weight would be in pounds, but how big a column would it be?"

"O, as big as my hand," replied Rollo.

"Yes, as big round as your hand at the bottom."

"Yes, sir," said Rollo, "and as high as up to the top of the tub."

"But suppose the tub was not quite full."

"O, then," replied Rollo, "only as high as to the top of the water."

"Suppose the hole was in the side of the tub, instead of in the bottom?"

"Then it would be just the same," said Rollo.

"That is," continued his father, "the pressure would be equal to the weight of a column as large round as your hand, and as high as from the surface of the water down to — what?"

"Why, down to the hole," said Rollo.

"Which part of the hole?" asked his father; "to the top, or the bottom?"

"O, to the middle," said Rollo; "that would be the average."

"Well," said his father, "do you think you could hold your hand so, covering such

a hole in the side of a tub full of water, and keep it in ? ”

“ Yes, sir,” said Rollo, “ easily enough.”

“ Hold out your hand a minute,” said his father.

Rollo held out his hand, as his father had requested.

“ Now,” said he, “ put the other hand up over it about as high as from the bottom to the top of a tub.”

Rollo did so, and said, —

“ There, I should think that the top of the tub would come about here.”

“ Well, now, should you be strong enough to hold up in your hand a piece of ice as large round as the palm, and as high as that ? ”

“ Yes, sir,” said Rollo, “ only it would be very cold.”

“ Never mind that ; I only suppose it to be ice, because you can more easily imagine ice in the form of such a column than water ; though ice would be lighter, and so it would take a longer column. Now, consider how hard a pressure you would have to resist to stop such a hole near the bottom of a *hog-head*, if it was full of water.”

“ Why, then, ” said Rollo, “ I should have

to hold hard enough to hold up a column as long as the hogshead."

"And could you do that?"

"No, sir," said Rollo, "I don't think I could."

"If you were to try, by putting your hand over the hole when the hogshead was empty, and then letting them fill it up gradually, at last you would find it impossible to resist the pressure, but the water would spirt out between your hand and the hole in all directions."

"I wish I could try it," said Rollo.

"I don't see but that you understand what I explained to you pretty well," said his father. "You see what the calculation depends upon, so that I am not so much inferior to Miss Mary as a lecturer, after all. Well, now you may go and tell Jonas about your dam."

So Rollo left his father, and ran off to look for Jonas. He found him in the barn, pitching down some hay for the horses.

"Well, Jonas," said Rollo, as he climbed up the ladder, to the scaffold where Jonas was standing.

"Well, Rollo," answered Jonas.

"I've come to tell you about our dam."

"Yes," said Jonas, "I see you have got a fine head of water in it."

"Head of water?" repeated Rollo, interrogatively. He did not know exactly what Jonas meant.

"Yes," said Jonas, "head of water. The perpendicular height of water raised by a dam, they call the *head*. I should think that you had eight or ten inches head."

"Father calls it *column*," said Rollo.

"Column?" repeated Jonas, interrogatively, in his turn.

"Yes," said Rollo, "column."

Rollo was not quite right in this; for his father had not used the word *column* in the same sense and connection in which Jonas used his phrase. However, he forgot this apparent disagreement immediately, for Jonas told him that he ought not to have left the plugs in, when he came away from the dam.

"Why not?" said Rollo.

"Because," said Jonas, "if you had taken out the plugs, the water would have been let off through the holes, and would not have risen so high."

"But we want it to rise high," said Rollo.

"Not when you are at home, and in bed and asleep," said Jonas.

"Will it do any harm?" said Rollo.

"It puts your dam in danger," said Jonas.

"How?" said Rollo.

"Why, in two ways," said Jonas. "In the first place, the higher it rises, the greater the pressure will be about the under edge of the board, and the greater the danger is that the dam will blow."

"Blow?" said Rollo; "what do you mean by blow?—leak? If it does leak a little, we can stop it again by hoeing on more sand and gravel."

"You'll find, I rather think," said Jonas, "that your hoeing on sand and gravel will not do much good, in stopping a hole, when you have ten inches' head of water on."

Rollo did not understand all this very well, but he asked Jonas what the other danger would be.

"Why, the water, now, has no way of escape but over the top of the board; for it must continue to run in until it fills the dam full, and then the surplus will run over the top. Now, the water which runs over will fall down close to the under side of the board,

and will gradually dig out a hole there ; and it may before to-morrow morning undermine the dam, and let the water through."

"Then," said Rollo, "I wish I had taken out the plugs."

"Yes," said Jonas, "that would have been safer. However, there is one advantage in leaving them in, and letting the water run over."

"What is that?" said Rollo.

"Why, all the dirt and leaves, &c., will be drawn off from the surface of the water, and will run over the dam, so that, if the dam stands safe until morning, the water will be clear and beautiful."

"Then," said Rollo, "I'll let it stay as it is."

"And take the risk?" said Jonas.

"Yes," said Rollo ; "Miss Mary will like to see it look clear and beautiful."

"Is she coming to give you another lecture?" said Jonas.

"Yes," said Rollo, "I hope she will."

"Well," said Jonas, "and to-morrow evening I'll come, and give you a lecture."

"O Jonas," said Rollo, laughing, "you cannot give a lecture."

"Why not?" said Jonas.

"O, because," said Rollo, "Miss Mary is a teacher."

"So am I," said Jonas; "at any rate, if you will get James to come and help you make an audience, you may see if I can't lecture."

"Well," said Rollo, "we will."

QUESTIONS.

What was Rollo thinking of when he was looking over the bridge? How was he going to ascertain whether the surface of the water was level? Did he find that there was any current? Is a pond generally perfectly level? How did Rollo's father show that a pond would generally have a descent? What is a column? How is the pressure of water upon any part of the bottom of a vessel measured? How is the calculation made when the part is upon the side of the vessel? What peculiar expression did Jonas use when he was speaking of Rollo's dam? What did he mean by it? Did he think that the dam was perfectly safe? What two dangers did he think it exposed to?

CHAPTER VIII

BLOWING

ROLLO had another lecture from Miss Mary before he had an opportunity to listen to Jonas's performance. The appointment for this second lecture of Miss Mary's was made in a somewhat singular way, as follows:—

The morning after the conversation with Jonas on the scaffold in the barn, Rollo rose early to go down before breakfast, and see if his dam had been carried away. To his great joy, he found it all safe. The water, too, was beautifully clear and transparent, and it extended, in a smooth and glassy sheet, for a considerable distance, up between the banks of the brook. A thin sheet of water was gliding over the edge of the board, and falling down into a little basin, which it had itself made in the sand below. Thence it meandered off, down the bed of the brook, and, as far down as Rollo could see, the little

stream appeared to flow quietly along, just as if no dam had been built.

Just at this moment, Rollo's eye caught something white upon the top of one of the stakes which Jonas had driven down behind the board to support it in its place. It was a piece of paper folded once. A small stone from the brook was laid upon it, to keep it from being blown away. Rollo took the stone off, and found his own name written upon the back of the paper. He opened it, and read as follows:—

“DEAR ROLLO,

“In taking my morning walk, I came down to see your dam. How beautiful and clear the water looks! I shall take a walk again this afternoon at five o'clock, and, if you and James will be here, I will come and give you a rather lecture.

MISS MARY.”

Rollo was very much pleased to receive this note.

“I wish,” said he to himself, “that I had known that Miss Mary was coming here so

early ; for then I would have come down too, and so I should have been here with her. No, I don't, either," said he ; "for then I should not have had this note."

Rollo showed the note to his mother at breakfast, and she gave him leave to go after dinner and ask James to come and play with him that afternoon, so as to be ready to hear Miss Mary's lecture at five o'clock. It was about three o'clock when James came, and they found all safe at the dam.

Rollo soon proposed that they should pull out the plugs, and let the water run out of the holes, instead of running over the board, for, as he told James, Jonas said that that would be safer.

"It would be a pity," said he, "to have our dam carried away now, before Miss Mary comes."

"Well," said James, "let us pull them out."

So the boys pulled out the great plug, but they could not get the small ones out. In fact, the great one, which they did pull out, came very hard. Rollo said he wondered what made it come so hard. The reason was, that it had swelled, and so had become

very tight in the hole. Wood always swells when it is soaked with water. This property of water to swell wood, by insinuating itself into its pores, was a property which Rollo was not acquainted with ; or, if he had heard of it before, he did not think of it now, in application to this case.

“Do you think, James,” said Rollo, “that the water will run out through this hole as fast as it comes down the brook, so that it will not run over the top of the board ?”

“I don’t know,” said James.

“We shall soon see,” said Rollo ; “let us go and sit down upon the bank, and watch it.”

So they went, and sat down upon the bank, and watched the water, as it spouted out of the hole. The water very soon ceased to run over the top of the board. This was in such a dry season of the year, that very little water was flowing in the brook ; so little, that it could flow out through the hole a little faster than it came in from the brook above. Of course the surface of the water in the pond, formed by the dam, began to subside, and, after a few minutes, it had settled as much as an inch below the edge of the board.

"We shall lose all our pond," said James.

"No," said Rollo, "it will only settle down as far as the hole, and that will leave considerable water in the dam. And then besides," continued Rollo, "when it has all run out, down to the hole, we can put the plug in, and let it fill up again."

They watched the water for some time, but they found that pretty soon it did not spout out as far as it did at first. The jet seemed to be less and less powerful, as the water settled gradually on the inside; because, as Rollo's father would have expressed it, the column of water that produced the pressure which forced the water out through the hole, was gradually diminishing in height; or, as Jonas would have stated it, there was less head of water in the dam, to force the water through.

The boys waited for some time, expecting that the surface of the water would subside to the level of the hole; but it did not; it settled slowly down, until it was only about two inches above the hole, and there it seemed to stop. After watching it for some time, they did not perceive that it was settling any farther. They wondered why it did

not continue to subside until it reached the level of the hole where it was running out.

"Why, the reason is," said James, "that the hole is not big enough."

"Why, it is a pretty big hole," said Rollo.

"Yes," replied James, "but it is not big enough to let the water through so fast as it comes into the dam down the brook."

"Why, yes it is, James," replied Rollo; "for, when we first pulled out the plug, it let the water run out faster than it ran in, and lowered the water in the dam. I don't see why it don't keep on lowering it."

James could not remove this difficulty, and so Rollo put the plug in again, and let the dam fill up. Then he pulled out the plug, and saw that the water settled quite fast for a time, until the surface had subsided about to the same level as before; but it did not go down as low as to the top of the hole.

He could not explain this remarkable operation at all, and they determined to ask Miss Mary to explain it in her lecture.

Miss Mary came about five o'clock, and the boys immediately asked her to explain why the water did not all run out through the hole, since a part of it could run out so

easily. They then, in order to show Miss Mary that the difficulty was a real one, put the plug in, and let the dam fill up. Then they pulled it out, and very soon the water began to settle.

"There," said James, "you see the hole is big enough to let out all the water that runs in the brook; for see!" he continued, pointing to the little stream which was running in all the time, at the head of the pond, "see! the water keeps running in, and it must run out faster through the hole, or else it would not go down."

"Yes," said Miss Mary; "it certainly runs out faster now that the whole pressure is on."

"What whole pressure?" asked Rollo.

"Why, the whole pressure of the water. For the dam was full when you took the plug out, and so the hole was about six inches below the surface of the water; and thus there was the pressure of a column of six inches, to force the water out; and you see it spouts out with considerable force. But by and by, if the water should subside until it is down within two inches of the hole, then there would only be a column of *two* inches

pressing ; and, accordingly, it would spout out with only one third the force. This, very likely, would not carry it off as fast as it comes in. So, in fact, the water will subside until the height of the column is just enough to force the water out as fast as it fills up, from the brook above, and then the surface will remain stationary."

In order to make this plain, Miss Mary asked the boys to pull out all three of the plugs, and she would try the experiment in another form.

"They won't come out," said Rollo.

"Why not?" said Miss Mary.

"I don't know," said Rollo, "only they won't come out."

"I wish that I could get down to them," said Miss Mary ; "I rather think I could get them out."

After some hesitation, she at length stepped cautiously down upon the pieces of wood which the boys had placed below the dam, and very carefully pulled out the small plugs. They were in very tight ; even Miss Mary found it very hard to draw them out.

"There," said she, "now perhaps the water will all run out, as low as the lowest hole."

Miss Mary was right. The water did settle down very low, nearly or quite down to the top of the large hole.

"Now," said she, "we will put in the two small plugs, and leave the large one out, and we shall see what the effect will be."

So the boys went and sat down with Miss Mary upon the bank, and watched the effect.

"You see," said Miss Mary, "that the water is gradually rising. The great hole is not large enough to let the water pass through as fast as it comes in above, unless there is some pressure upon it. The water is rising."

"Yes," said James, "I can see a little stick by the shore, which is almost covered; there, the water is over it."

"But, as the water rises," said Miss Mary, 'you see it presses harder and harder through the hole, and the jet spouts out farther and farther.'

"Yes," said Rollo, "I see it does."

"Now," continued Miss Mary, "after a time, the water will rise so high as to produce a pressure great enough to force the water through as fast as it comes down from above. Then the coming in of the water from above

and its escape through the hole, will be just equal, and the water will neither rise nor fall. The effect of the supply coming in from above, tending to raise the water, and that of the escape from the hole, tending to lower it, will be in equilibrium."

"*Equilibrium!*" said Rollo; "what does that mean?"

"It means that they will be exactly equal, so as to balance each other," replied Miss Mary.

"Now," continued Miss Mary, "if the hole were smaller, the water would have to rise to a higher level before the pressure would be sufficient to carry out the water as fast as it comes in."

"Let us try it," said Rollo.

"Well," said Miss Mary, "we can try it by means of one of the small plugs."

So Rollo went down to the dam, and took out the lower small plug, and put in the large one. The lower small plug was just at the level of the large one, and of course the water passing out of it was subject to the same pressure. And though the jet was smaller, because the hole was smaller, yet it spouted out to about the same distance.

Rollo came back to the bank, and they found that the water gradually rose until it nearly reached the top of the board, and still continued rising.

"I don't believe but that it will run over," said Rollo.

"Very likely," said Miss Mary; "you see that that hole is a great deal smaller than the other, and of course it will take a great pressure to force the water through as fast as it comes in from above."

"How much smaller is it?" said James.

"It is not more than half as large," said Rollo; "exactly half as large; for Jonas bored the large hole with an inch auger, and the small hole with a half inch auger."

"Then it is only a quarter as large," said Miss Mary.

"Why, Miss Mary!" said Rollo; "a half an inch only quarter as large as an inch!" and he laughed heartily that Miss Mary should have made such a mistake in her mathematics.

"I admit," said Miss Mary, "that the small hole is just half as large in *diameter* as the large hole; but then it is only a quarter as large in *area*."

"I don't know what you mean," said James.

"Why, *diameter* means the distance across it, and *area* means the whole space. Now, it is certainly only twice as far across the large hole as it is across the small hole; but, then, the space is four times as great."

"Why is that?" asked Rollo.

"Because," said Miss Mary, "the large hole is not only twice as long, but it is twice as broad as the small one. You can understand it better by supposing two square boards. If you had one square board a foot long, and a foot broad, and James had one half a foot long and half a foot broad, yours would be four times as large as his, because it would be twice as large both ways. If you were to saw yours in two, through the middle, each half would make two like James's."

"Yes," said Rollo, "so it would. But then these holes are not square; they are round; and that might make some difference."

"No," said Miss Mary; "it makes no difference. The mathematicians have proved that it is always so with circles as well as squares. If one circle is twice as far across

as another, it is four times as large, or, in mathematical language, if the diameter is twice as great, the area will be four times as great."

"Well," said Rollo, "and now about the plugs."

"Yes," replied Miss Mary, "let us now reason about the plugs. The small hole will only let through a quarter part as much water as the large one, with the same pressure; and of course there must be four times as much pressure to make the same quantity of water pass.

"Yes," said Rollo, "and so the water must rise four times as high."

"I believe so," said Miss Mary; "that is, if four times the height of water would make exactly four times the pressure; and I believe it would. Now, I think the water cannot rise four times as high without going over the top of the board, and of course you cannot, with this dam, get a pressure sufficient to carry all the water through that opening."

"It is running over," interrupted James; "see, it is running over!"

It was beginning to run over a little, here and there, along the edge of the board, as

James said. Jonas had been careful, when he put the board down, to make the upper edge as nearly level as he could get it; and then, when he came up from his work, the first night after it had been made, he stopped a moment to look at it, to see if the water was running over it equally. He found, by the running of the water, that one end of the board was a little higher than the other, and he drove it down a little with his axe; and then the water glided over the edge of the board in one regular sheet, of equal thickness from end to end.

And now, therefore, when the water began to run over, it began in various places all along the edge of the board. At the same time, the jet from the small hole was spouting away with very considerable force, carrying off a large portion of the water, but not the whole.

"I wish," said Rollo, "that my dam was a little higher, and then perhaps the water would rise high enough to force it all through the small hole."

"Couldn't you put another board on?" said Miss Mary.

"O yes," said Rollo, jumping up and clapping

ping his hands, "we will: James, we will. If you will wait here, Miss Mary, for us. James and I will go up immediately and get another board."

Miss Mary promised to wait; and so Rollo and James set off towards the house. They first, however, took the measure of the length, so that the board should fit to its place. When they got up to the house, they found a board very easily; but they had some difficulty in sawing it off, neither Rollo nor James being much accustomed to the use of the saw. Rollo worked upon it for a time, and, when he was tired, he gave the saw to James. However, they got it sawed off at length; and then they took it, one boy at each end, and carried it down to the dam. Then they placed it very carefully upon the top of the other board, pressing it down hard upon it, and letting it lean back against the stakes which Jonas had driven in, and which were long enough to support this additional board, as well as the one first put down. The whole operation seemed to succeed perfectly.

The new board was not so wide as the other; it was not more than five or six

inches wide, while the other was nearly a foot. Still they thought it would be wide enough.

“It will raise the water half a foot,” said Rollo, “and that will put a great deal more pressure on.”

But they found that the two boards did not fit together very well, and some water escaped through the crack between them. Rollo endeavored to drive the upper board down closer to the lower one, by striking the upper edge of it with a sort of club which he picked up upon the bank. He did, in this way, make the junction of the boards somewhat closer, but still some water would find its way through.

However, notwithstanding this, they soon found that the water was slowly rising up the side of the upper board; and of course, as the depth increased, the pressure increased too, and the jet of water from the hole which was near the bottom of it was thrown out with greater and greater force. They all thought that probably, before the water got as high as to the top of the upper board, the pressure would be great enough to force it out as fast from the hole as it came in from

the brook above ; and it is very possible that it might have been so, had not the progress of the experiment been interrupted in a singular manner. The dam *blowed*.

And this was the way. They were standing together near the bank, looking at the jet of water, which was spouting away beautifully to a considerable distance down the stream, when James, who had been looking down into the water, said suddenly, —

“ O Rollo, see that little stick sailing round and round.”

Rollo looked down where James pointed, and saw a small stick slowly revolving in the water, in the corner near one end of the dam, close in by the bank. Both Rollo and Miss Mary watched it for several minutes, wondering what could make it move in that curious way. The stick revolved faster and faster ; and presently there seemed to be a small depression in the water, and a little leaf, which was floating near, began to move round in the same way.

“ It is a little whirlpool,” said Miss Mary.

“ Yes,” said Rollo ; “ what a beautiful little whirlpool. What makes it, Miss Mary ? ”

“ I don't know,” said Miss Mary. “ I

have often seen such little whirlpools in the water, though not generally in such still water as this."

"It grows bigger," said Rollo.

It was indeed growing a little bigger. The depression in the centre became deeper, and the little sticks and leaves were whirled around in it very rapidly — phenomena which seemed to puzzle both Rollo and Miss Mary a good deal, until their surprise was increased by a discovery which Miss Mary made of another strange appearance.

Just below the dam, at the same end of it, Miss Mary observed a strange commotion in the sand, and a sort of boiling up of water like a boiling spring.

"See, children!" said she; "see there."

"What is it?" said James.

"What makes it?" said Rollo.

"O, I understand, now," said Miss Mary. "It is a leak. The dam has sprung a-leak. There is a hole underneath, and the water goes down in the whirlpool, and then comes boiling up on the under side."

"So it is," said Rollo. "But I'll stop it. I'll get some sand on my spade, and stop it."

"O no," said James; "then you'll spoil the whirlpool."

"Well," said Miss Mary, "it is better to spoil the whirlpool than the dam."

"But it won't spoil the dam," said James. "It does not hurt the dam at al'. It makes it prettier."

"But it will wear the hole out bigger and bigger," said Miss Mary, "until it carries the dam all away. See, it is growing bigger now very fast; get some sand and gravel, and stop it quick, Rollo."

Rollo hastened about, trying to get his spade into the ground here and there to get some sand or earth to stop the leak with; but the greensward was so tough, and there were so many roots of trees among the grass, that he could not get any.

"Dig here, Rollo," said James.

James pointed, as he spoke, to the sand and gravel in the bed of the brook below the dam; and Rollo ran there with his spade, and immediately began digging with his spade among the loose sand and gravel which was lying there.

"Chuck it right into the whirlpool," said Miss Mary.

"Rollo found the digging very easy, and took up spadeful after spadeful of sand, and threw it into the whirlpool. In a few minutes, however, the water, which had boiled up on the lower side of the dam, began to be so abundant, that it interfered very much with his digging. The jet of water, too, spouting from the hole, was in his way; and, besides, he was soon out of breath. He accordingly said he must stop to rest a minute, and he stepped out upon the bank, and they all looked down at the whirlpool to see whether he had done any good.

No; the water whirled as violently as ever, and it boiled up below, they thought, with increased force.

"I don't believe we can stop it," said Rollo.

"Here's a good place to dig," said Miss Mary. She pointed to a projecting bank a little way up from the dam, where the earth seemed soft, and pretty free from grass and roots.

"Let me have the spade," said James, "and you rest, Rollo."

So James took the spade, and began to dig in the bank. It was pretty easy digging, but

James was not quite strong enough to throw the spadeful of earth so far. The first spadeful stuck to the spade a little, and fell into the middle of the dam. The second fell a little short of the whirlpool, where it could do but little good.

“Let *me* have the spade,” said Miss Mary; “I can dig.”

Miss Mary was so much interested in saving the dam, that she wanted to try; but she did not succeed much better than the boys. She had to crowd the spade into the earth by the strength of her arms, instead of pressing it down with her foot, as the boys had done; for her shoes were too light and thin for such a purpose. In her attempt, therefore, to use a spade, she made somewhat such a figure as a boy makes in attempting to sew without a thimble.

However, she accomplished something. She threw several pretty good spadefuls directly into the mouth of the whirlpool, and Rollo thought that they would certainly stop the leak. Instead of that, however, the vortex seemed to swallow them up in an instant, and itself to grow larger and larger continually.

"It's of no use," said Rollo, at length "and, in fact, I remember that Jonas said it would do no good to shovel in sand and gravel with ten inches head on."

"Head on!" repeated Miss Mary.

"Yes, head of water," said Rollo.

"O, he meant the pressure of the ten inches of water."

"Yes," said Rollo.

"I forgot that," said Miss Mary. "The hole is down at the very bottom, and so there must be a great pressure. The pressure drives the water through the leak with as much force as it does through the hole, and that carries every thing that we throw in right through."

"Only see how the water has fallen," said Rollo.

It had fallen very much indeed. It was below the top of the lower board, and was fast settling lower still. The jet from the hole in the board had very much diminished in force, but it was still flowing. The whirlpool had, however, become very large, as large round, and almost as deep, as a water-pail; and the water, with great quantities of sand and gravel, came boiling up on the lower

side. They saw very plainly that a monstrous hole had been made under and around the end of the board, which it would require a great deal of gravel to stop again.

"We never can stop it, in the world," said Rollo.

"Jonas can," said James.

"I am not certain that you cannot mend it yourselves," said Miss Mary.

"O Miss Mary," said Rollo, "if we couldn't stop it when it first began, and was small, we certainly can't stop it now."

"Why, then the pond was full," said Miss Mary, "and there was a great pressure upon it; but now, after the water is all out, and there will be no pressure, you can fill up the hole by wheeling in earth with your wheelbarrow, perhaps."

"Perhaps we can," said Rollo, despondingly; "but I think that Jonas can mend it better."

They all stood for several minutes, gazing in silence upon the ruins of the dam, as the last of the water poured out through the great opening which the pressure of the water had made. At last Miss Mary said, —

“ Well, boys, I am sorry that the dam is gone.”

“ So am I,” said Rollo. “ It is because I put on the upper board.”

“ I think it very likely,” said Miss Mary ; “ that increased the pressure, so as to force a hole through under the board.”

“ I expect that is what Jonas meant by *blowing*. It is a strange sort of a name, 'seems to me.”

“ It is a strange sort of a thing,” said Miss Mary, “ 'seems to *me*. But, at any rate, we have all learned something about the pressure of water by it.”

“ Yes,” said Rollo. “ I'll tell Jonas all about it when I get home.”

Here Miss Mary bade the children good by ; and she went home her way, and they went theirs.

QUESTIONS.

How did Miss Mary make the appointment to meet Rollo and James ? What did the boys find the state of the dam when they went to it ? Was the water running over : When they pulled out the large plug, did it at first d s

Charge the water as fast as it came in? Did it cause the water to subside? Did it continue to subside as long as the boys expected? What question did they have ready to propose to Miss Mary when she came? What experiments did they perform in presenting their question? How did Miss Mary explain the difficulty? Why could not the boys get the small plugs out? What was the design of the boys in raising the dam by another board? What was the first indication that the water had forced a hole under the dam? Describe the efforts which they made to stop it.

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CHAPTER IX.

BRIDGE BUILDING.

ROLLO could not tell Jonas about the dam that night, because he had gone away, and was not to come home until after Rollo had gone to bed. He, however, told his father all about it. He described to him, first, how they had drawn off the water from their dam, with their plugs, and the explanations which Miss Mary had made of the principle, — namely, that the water would rise until the pressure was great enough to force it through the hole as fast as it would come in from above.

“Yes,” said his father, “Miss Mary was correct; and that is a very important principle. It explains an effect which we have seen taking place a thousand times.”

“O father,” said Rollo, “I never saw it before.”

“You never *observed* it before, you mean,” replied his father.

"No sir, I never *saw* it before. I'm sure I never saw a brook dammed up before with a board, so as to make all the water run through a little round hole."

"Suppose the hole had been a square hole; would it not have been the same thing?" asked his father.

"Yes, sir," said Rollo. "The shape of the hole makes no difference."

"And suppose, instead of a board, it had been a great flat stone, with a hole drilled through it?"

"Just the same," said Rollo.

"Or two stones," continued his father, "with a narrow, confined place between them?"

"Then you could not plug it up," said Rollo.

"But plugging it up has nothing to do with the effect produced while it is open. Your apparatus was, in fact, essentially, only a partial obstruction to the stream. Had there been no opening for the water, it would have been a *total* obstruction. As it was, it was a partial obstruction. There was a confined and narrow passage for the water."

"Yes, sir," said Rollo, "a half-inch hole."

"Now, the same principle, which governed the motion of the water," said his father, "in the case of the artificial obstruction which you made, governs it in the case of the *natural* obstructions formed along the bed of the brook, by narrow banks or stones; so that, by walking along the brook with you, some day, I could perform precisely the same experiment, and in fact show it to you, as performed by nature before you, in many places."

"O father," said Rollo, "I wish you would."

"I will, some time when I am at leisure. Or you can do it for yourself, and show James and Miss Mary."

"But I don't think I can find the places," said Rollo.

"O yes," said his father, "find any places where there are obstructions. There is one place I recollect, just above where you dug up a little pine-tree. There are two great stones, or rocks, leaning against each other, with a narrow passage between them."

"Yes, sir," said Rollo, "where James and I always step over, — except when there is a freshet."

"Now, that," continued his father, "is a

narrow and confined place, and the water cannot come through as fast as it comes down from above."

"It can now," said Rollo.

"Then it is because the water is very low," said his father.

"Yes, sir," said Rollo, "the water is very low."

"But when the brook is as full as usual it is too small. All the water cannot get through without an extra pressure upon it to force it. So you will find, if you examine the place at some time when a good deal of water is running, that the surface of the water above the obstruction will be considerably higher than it is below. The reason is, as Miss Mary's experiment shows very satisfactorily, that the water cannot all get through without running a great deal faster than it does in other parts of the brook, where it has more room. And it will not run any faster unless it is forced to, by a pressure from behind; and thus the water behind accumulates and rises until it furnishes a pressure sufficient to force the water through the narrow place."

"Yes, sir," said Rollo, "I remember that

there is a deep place above the rocks, — a kind of a pond.”

“And always,” continued Rollo’s father. “any obstruction whatever in a brook or river, whether by shallows, or rocks, or projecting banks, or a narrow bed, raises the water above the obstruction. The piers of a bridge are a remarkable instance.”

“What are the piers of a bridge?” said Rollo.

“Why, when people build a bridge, they have to build up some stone work upon the banks, on each side, to support the ends of the bridge. These are called *abutments*. Then, besides, if the river is wide, they generally have to build some supports for the middle of it.”

“What, right in the water?” said Rollo.

“Yes, and these are called *piers*. In stone bridges, across wide rivers, there are a great many piers; and the road way goes across from one to the other, over arches. In wooden bridges, they do not have so many piers, because the long beams will extend pretty far. But, in all cases, every pier which is built upon in a river, takes away from some of the space that the river had to flow

in, and so narrows the channel. Now, every body that has observed the effect of bridges, knows that this always makes the water above the bridge stand at a higher level than it did before;—but every body does not know what the *principle* is which regulates the height of this level. Can you tell me what it is?”

“Yes, sir,” said Rollo; “it rises till there is pressure enough to force the water through between the piers.”

“Yes,” said his father, “and there is great advantage in knowing the principle, for then they can calculate from it how great the rise will be.”

“How?” said Rollo.

“Why, first,” replied his father, “they calculate how much the piers diminish the space which the water had to pass in. Then from that they can tell how much swifter it must pass in order to go through in the same time. Then they can calculate how much the water must rise to give a sufficient pressure to effect this.”

“Yes,” said Rollo, “Miss Mary calculated how high the water must rise before it could go out fast enough through our small hole.”

“That is the advantage of understanding principles as well as learning facts,” said his father. “Understanding principles enables us to make calculations. But now you must go and amuse yourself. I cannot talk with you any more.”

“Well, father, only just tell me one thing. How is it that they can build piers out in the middle of a river?”

“O, there are several ways of building below the surface of the water,” said his father. “One way is by a diving-bell.”

“A diving-bell?” repeated Rollo.

“Yes; that is a large, heavy apparatus, shaped like a bell, but large enough to hold two or three men. Then it is let down into the water, mouth downwards.”

“Why, father, the man would fall out, and sink to the bottom.”

“O, they have a kind of shelf across for the man to sit upon, and another for his tools,” said his father, “and so they lower him down to the bottom of the water. The air in the diving-bell is for him to breathe. Then, when the man is down near the bottom, they can lower a stone down to him, and let

him guide it exactly into the place where it ought to go."

"What is another way?" said Rollo.

"Another way," said his father, "is to drop large stones into the water all over the place where the pier is to be, and thus fill up to the surface; and when they have got a large place filled up to the surface of the water, then they can begin to place the stones regularly."

"That is the easiest way," said Rollo.

"Yes," said his father; "but then it wastes the stone; because the stones that are dropped in, spread out in every direction over the bottom of the water, and so a great many more are required than would be necessary if they were built up perpendicularly, upon a foundation no larger than the pier itself was to be.

"And besides, there is another difficulty," continued Rollo's father. "The stones thus spreading out in every direction occupy a great deal of the space under water between the piers, so that the water has less room for its flowing. Of course the water will rise much higher above the bridge, on account of this increased obstruction. For, according

to our principle, it must rise high enough to produce a pressure sufficient to force all the water through or over the obstructions."

"Well, sir," said Rollo, "and what harm does it do for the water to rise?"

"Why, it might overflow the land above, especially the intervals and meadows. Then, in high floods, in the spring of the year, when the ice is coming down, it might rise high enough for the ice or floating timber to strike the bridge itself, and carry it away off from the piers. Then, besides, the more obstruction there is between the piers, the more rapid the current must be; for, if it has a narrow or a shallow place to go through, it must go through so much the quicker; and this would prevent boats coming up under the bridge, and make it dangerous for them to go down."

"There seems to be a great many difficulties," said Rollo.

"Yes," said his father; "and so engineers always consider it very important, in building bridges, to obstruct the passage of the water as little as possible. Every thing they do must obstruct it in some degree. Even a single post put in, to support the middle of a

bridge narrows the channel for the passage of the water, and so prevents a part of the water from passing, until it rises enough above, to put on a sufficient pressure to force it through enough quicker to make up for the narrowness of the space."

"I should not think one post would make any difference," said Rollo.

"It would not, probably, make any *sensible* difference," said his father, "but it must make a real difference; for, if one post did not make any difference at all, another might be put in, without making any, and another, and another; and thus a whole row of posts might be put in, extending from bank to bank, without making any obstruction. The fact is, that any obstruction whatever must raise the water above it in the proportion which the obstruction bears to the whole breadth of the river. Therefore, in building bridges over running streams, they are always very careful to make as little obstruction as possible. They make as few piers as will answer to support the bridge, so as to have as wide spaces between them as they can. They make them as narrow, too, as they can; and

they build them up compact and solid from the bottom."

"Then it won't do to tumble the stones in," said Rollo.

"No," replied his father, "they can only do that in lakes and in the sea, when they want to build a lighthouse, or a mole, or a breakwater."

"A mole?" said Rollo; "what is a mole?"

"Why, I can't tell you about a mole now very well," said his father; "I have spent more time now in talking to you than I could well spare."

"Well, father, then you need not tell me any more; only there was another way of building foundations under water, that you did not tell me of. But that will do as well some other time, if you want to be busy now."

"No," replied his father, "I will tell you about that now, as it will only take me a minute or two. It is by what they call a *coffer dam*."

"I never heard of a coffer dam," said Rollo.

"No, probably not," replied his father

‘The way they make a coffer dam is, by driving two rows of piles, at a little distance from each other, into the bottom of the river, all around the place where the pier is to be built. Then they fill up the space between these rows with earth or clay. This makes a tight wall all around the place where they want to work. Then they can pump out the water from inside this wall, or coffer dam, as they call it.’

“What makes them call it a *coffer* dam?” said Rollo.

“Why, *coffer* means *box* or *chest*; and it is a sort of box dam, enclosing a certain space all around.”

“And so they have a good, dry place to work in,” said Rollo.

“Yes,” replied his father; “though they may have water all around them, ten or fifteen feet high.”

“I should like to see a coffer dam,” said Rollo.

“You would be very much interested in seeing one, I have no doubt,” said his father “But this is all I can tell you, now, about working under water.”

QUESTIONS.

What did Rollo's father say about the principle which Miss Mary had explained? Had he ever himself observed the operation of it? In what sort of cases? What is always the effect of narrowing or obstructing a stream, in respect to the level of the water above it? What is an *abutment* in bridge building? What is a *pier*? What effect do the piers of a bridge have upon the level of the water above? What effect do they produce upon the current? How many ways did Rollo's father mention of laying foundations under water? What was the first mode? What was the second mode? Is this second mode suitable for the piers of bridges? Why not? In what cases is it suitable? What is the third mode mentioned?

CHAPTER X.

MOMENTUM

BESIDES the pressure of water, there is also its momentum. Pressure is the steady force which it exerts by its weight. Momentum is the force of its *impulse*, when it is in motion. The waves of the ocean dashing against a ship in a storm, furnish an example of momentum. The water spouting up through a leak in the bottom of a ship, is forced upward by pressure. A brook may destroy a dam by the momentum of the water, as well as by its pressure. This Rollo learned in the manner to be described in this chapter.

When he left his father, he went away, intending, the next time he saw Jonas again, to ask him whether they could not make a coffer dam, some how or other, around the hole in their dam, and so get a better opportunity to repair the breach.

He went out into the back yard, wishing

that Jonas was at home ; but he had not come. Rollo found, too, that it looked like rain. He was glad of it, he said to himself, as it would make the brook higher, and so the water would spout out more swiftly from their jets. Rollo was mistaken, however, in this opinion. He forgot that the force of the jet depended upon the height of the dam, and not upon the quantity of water which came down the brook. The surplus water, in case of a flood in the brook, would all flow over the top of the board, without much affecting the pressure on which the force of the jet depended.

However, Rollo was very glad to see it looking like rain ; and he was still more pleased, a few minutes afterwards, at feeling a little drop falling upon his cheek.

That night, when he went to bed, Rollo looked out of the window, and found that it was raining very fast ; and he determined that he would get up early the next morning, and go down and see how his dam appeared. He thought it possible, that, when the brook was full, the water, coming down in a torrent, might perhaps wash new sand and gravel into the hole which had been made, and so mend

the dam itself. He determined that, at any rate, he would go and see.

The next morning, when he awoke, it was still raining. He got up, and dressed himself, and, when he came down stairs, he inquired how long it would be before breakfast. They told him about half an hour. He concluded, therefore, that he would wait until after breakfast, for he wanted a little more time than that.

After breakfast, he went up into the garret, where he used to keep what he called his *weather rigging*. This weather rigging consisted of clothes for him to wear out in the storms. He used often to like to take walks out in the storms to see the torrents, and the floods in the brook, and the great pools of water. His mother allowed him to go out on such excursions, provided that he would get Jonas to find something which would protect his common clothes from the mud and water.

Accordingly Jonas had ransacked the garret, and found an old great coat and an umbrella, also a straw hat, with a monstrous broad brim, which Jonas painted so as to make it impervious to water. He also had a pair of boots,

old and patched, but still tight, and they were kept water-proof by a kind of composition which Rollo used to put on them with a brush, when they were dry.

All this Rollo used to call his weather rigging; and he told his mother that the very pleasantest walks he had at any time, were those he made in the great rain storms, protected by his weather rigging.

On this occasion, Rollo rigged himself, as usual, for a storm excursion; and, with his umbrella over his head, he sallied forth into the rain. He found that the brook had risen considerably, but far less than he had expected. He proceeded slowly and cautiously; for, although he was impatient to see what effect the water had produced upon his dam, he knew that the paths were slippery, and it required some care and circumspection to go safely.

When he reached the dam, he found that the water was pouring over the board in a torrent,—so full and turbid that the board was entirely concealed from view. He could see the top of the stakes, but the narrow board which they had placed over the other seemed not to be there. He knew, however

that the lower board was still there, for there was a great waterfall at the place, which he thought could be produced only by the board's keeping its position.

There was a great whirl and boiling of the water below the dam, and Rollo looked at it very carefully to see if he could ascertain, by the appearance of it, whether the water passed *under* the board, as well as over it. But he could not tell. There were no signs of the whirlpool above, however, and Rollo could not help hoping that the flood had come and filled up the opening which the pressure of the water in the dam had made.

Rollo walked up the brook a little way, and was very much interested in observing the various appearances which the foaming and boiling torrent assumed in various parts of its course, according to the nature of the bank. In one place, the whole force of the stream dashed against a rock, which stood firmly in the very centre of the channel. In another place, it plunged, with many a whirling eddy, around a sharp curve, made by the bed of the stream. Here its course was almost choked up by sticks and brush-wood, which had drifted down, and caught in some

narrow part of the channel; and there it would shoot down a long, unobstructed descent, making a beautiful cascade.

Rollo remained for half an hour, watching the swift motions of the water in these and many other places; and then he went home. He remained at home until noon. After dinner, he looked out of the window, and found it still raining. He then went to his book-case, and began looking over books, with his little brother Nathan, where he became so much interested that he did not think much about the weather, until a little after two o'clock, when who should come in but James.

"Why, James!" said Rollo, "are you out in all this rain?"

"Rain!" repeated James. "It does not rain; it is all clearing away."

"Clearing away!" said Rollo, jumping up from his books; "then let us go down and look at our dam."

"Yes," said James, "that is what I came for."

"O, let me go too," said Nathan.

"No," replied Rollo, "you can't go, Nathan; it is very wet and muddy."

"We can draw him in his wagon," said James.

"Well," said Rollo, "if mother will let you go, Nathan; go and ask her."

Nathan ran off to ask his mother, and his mother said that he might go. Most mothers would not have been willing to let so young a child go out under the care of two such boys as Rollo and James. But Rollo was always so careful to keep him from getting wet and muddy, in such cases, that she generally consented.

So they put Nathan into a little cart or wagon which he had, and Rollo and James drew him along. They found that the clouds were all breaking away, and the sun coming out. It had not rained any for nearly an hour, so that the water had run off from the roads and paths. As they walked along, they talked together thus;—

"I went down this morning, James," said Rollo, "and the brook was a real torrent. I wish you could have seen it then."

"I expect it will be a real torrent now," said James.

"Not so much of a torrent as it was when I saw it," said Rollo.

“Why not?” said James.

“Because,” said Rollo, “it does not rain now. It rained very fast when I went down this morning.”

“Hark!” said James; “I hear something roaring down in the woods.”

“What is it?” said Rollo.

“I am afraid it is a bear,” said Nathan.

“A bear!” repeated Rollo, with a laugh; “you need not feel afraid of a bear, Nathan, in our woods.”

“It’s the brook, Rollo,” said James; “I believe it is the brook.”

“Yes,” said Rollo, “it is; how it roars! I don’t think it roared quite so much when I went down this morning.”

The boys went on the faster after they heard the roaring of the brook; and when they first came in sight of it, Rollo admitted that it was a great deal higher than it was when he saw it in the morning. It roared and tumbled along with tremendous violence. Rollo forgot, when he spoke as if the water might be expected to be the highest during the continuance of the rain, that it takes some time for the water which comes to the earth from the clouds, to find its way down

all the little rivulets and streams into the brook, and that, consequently, the water in the brook will be highest a short time after the rain is over.

In one place the water had overflowed the banks of the brook, and had spread all about under the trees, which thus seemed to be growing out of a pond. The rock which Rollo had observed, in the morning, breasting the torrent, was now wholly under water, and the stream showed no indication of its presence, except by a ripple. The boys noticed these things as they passed, but they hastened along to the dam to see what were the appearances there.

They could see no traces of the dam whatever. The water swept over the place, in one overwhelming and unbroken torrent. The boys stood upon the bank a few minutes, looking on in silence, and yet with great interest, until at length James said, —

“It is all carried away, isn’t it, Rollo?”

“I don’t know,” answered Rollo, “whether it has been carried away, or whether it is all there, — deep under water.”

“But the stakes, Rollo, the stakes! The stakes could not be covered with water

And so, if the dam was there still, we should see the tops of the stakes!"

Rollo did not reply, but he considered James's reasoning as unanswerable.

"Then," said he, after a short pause, "the stakes and the board have all gone down stream together, and that's the end of our dam."

"However," he continued, "at any rate, if we have not got a dam, we have got a cataract, and we will sail some ships down."

So the boys left Nathan in the wagon, in a place where he could see pretty well, and they began to launch into the water sticks of wood, and poles, and little logs, and other such floating substances as they could find around there, and then they amused themselves in watching them as they were borne, swiftly away down the stream; sometimes dashing first against one bank, and then against the other, sometimes shooting straight forward along the middle of the current, and now and then plunging headlong down a cataract, or a cascade.

In this sport they followed the stream down for some distance, until Nathan called out to them not to leave him so far behind,



SO THE BOYS LEFT NATHAN IN THE WAGON.—Page 160.



and then they went back to him, and, after about an hour, returned home.

The next day, Rollo came again to look at the brook; and he found that the water had subsided nearly to its accustomed level. He proceeded immediately to the site of the dam, and found that there were no traces of it remaining whatever; except the two little cuts in the mossy bank where Jonas had inserted the two ends of the board. The water was meandering slowly along the sandy bed of the brook, taking its own course unimpeded, and looking as if it was saying to Rollo, "Between these banks, I choose to have my own way."

About a month after this, as James and Rollo were at work among the bushes, at a considerable distance below where the dam had been built, James suddenly stopped cutting, and said, with a loud sigh, —

"O dear me! I am tired. I wish I had a good place to sit down."

"Well," said Rollo, "we'll look about and find a log or something. O, here is a board leaning up against these bushes."

He and James went to get the board, and, to their utter astonishment, they found that

it was the identical board which Jonas had put into the dam. They knew it by the plugs and holes. They got it out from the place in the bushes where it had been caught, and made a seat of it; and this was the end of their dam. As for the stakes and the narrow board, they never saw any thing of them again.

Thus their dam was first undermined by the pressure of the water in the brook, and then afterwards carried wholly away by its momentum.

QUESTIONS.

What effect did Rollo expect would be produced by the rain, and the consequent rising of the water, in the brook? Which would the force of the jet really depend upon, the quantity of water flowing in the brook, or the height of the water above the dam? What were the appearances of the brook when Rollo first went down? When he went down the second time, did he expect to find the water higher, or not so high? Why did he expect to find it not so high? How was it, in fact? Why was it higher after the rain was over? What was the appearance at the dam? Was the board carried away by the pressure or by the momentum of the water? What is *momentum*? Relate the circumstances under which they found the board

CHAPTER XI.

JONAS'S LECTURE.

ONE day, Rollo and Jonas were sent away by Rollo's father, about eight miles, into a neighboring town, in a wagon, to get some apples of a particular kind, called the Cherry Reds, from their color. They bought them of a farmer. They went early in the day, because they had to gather the apples themselves from the trees. Jonas and Rollo had to climb up into the trees, with baskets, and take off the apples, one by one, to prevent their being bruised ; for Rollo's father wanted to keep them all winter.

About four o'clock, they had finished gathering the apples. They put them into three great bags, which they put into the wagon behind the seat. They put in some straw first, to prevent the apples getting bruised by the jolting of the wagon. Rollo took two apples for himself, to eat by the way, and so they set out for home.

They went on very prosperously for some time ; but, at length, when they were still about five miles from home, down came the back of the wagon to the ground, with a violent shock.

“What’s the matter now ?” said Rollo.

“We’ve broke down,” said Jonas, “somehow or other.”

Rollo jumped out, and Jonas soon followed him. They found, on examination, that the hind axletree had broken short off, close to the wheel, and the wheel was lying down flat in the road, with the corner of the wagon resting upon the centre of it.

“And what shall we do now ?” said Rollo.

“Why, you and I have got to walk five miles home ; that’s all,” said Jonas.

“Five miles !” said Rollo ; “well, I can walk five miles.”

“Yes,” said Jonas, “I think it likely you can ; though you’ll get pretty tired.”

So saying, Jonas went into the woods by the side of the road, and, with a hatchet, which he always took with him in the wagon, to be ready in case of an accident, he cut a long and stout pole. This he brought to the road, and put it underneath the wagon,

resting one end of it upon the forward axle-tree, and letting the other end trail along upon the ground, behind. He then lifted up the back part of the wagon, while Rollo swung the end of the pole round under it, in such a way that the corner of the wagon, which had lost its wheel, rested upon the middle of the pole.

"There," said Jonas, "I think the cherry reds will ride now, and you and I must walk."

So he hung the end of the long reins over the seat of the wagon, for the horse was very gentle and steady, and would walk along quietly in the road; and he and Rollo followed behind.

"We shall be late home," said Rollo.

"Yes," said Jonas, "this will detain us an hour. They were to expect us about six, and it will be seven before we get home. It is rather bad to be cast away, but not quite so bad to be cast away on land as it is at sea."

"Were you ever cast away, Jonas," said Rollo, "when you used to go to sea?"

"No," said Jonas; "I did not go to sea a great while."

"Speaking of going to sea, Jonas," said

Rollo, "make; me think of water, and of the lecture which you promised to give us. I wish you would give it now."

"Yes," said Jonas, "I promised that, if you would get James to come down to the dam, I would give you a lecture; but this does not seem to be a very good occasion. I can't lecture very well without either the apparatus or an audience."

"I am very sorry our dam was carried away," said Rollo; "for we might have built it up higher, and so had it flow over a great deal of land, and make a pond; and then we might have sailed on it, in a boat."

"If you only had a boat to sail in," said Jonas.

"We could have got a box; a long box would do. It is not necessary — is it? — to have the end sharp?"

"No," said Jonas; "but a box would not be tight enough."

"Couldn't I sail a little in a tub?" said Rollo.

"A tub would be tight, at any rate," said Jonas.

"And wouldn't it bear me up?"

"Yes," said Jonas.

"Did you ever see any body sail in a tub?" asked Rollo.

"No," replied Jonas, "I never did."

"Then you mean," added Rollo, "that you *think* it would bear me up."

"No," said Jonas, "I am sure it would."

"But how can you be sure," said Rollo "unless you have seen it tried?"

"Because," said Jonas, "I know the principle that it depends upon."

"What is the principle?" said Rollo.

"The principle is," said Jonas, "that, if any thing is floating in the water, it sinks into it low enough to displace its own weight of water."

"I don't understand you very well," said Rollo.

"Well," said Jonas, "I can explain it better by taking a particular thing.

"We will suppose," he continued, "that there is a log of wood floating in the water. As far as it sinks down, it displaces the water; that is, it crowds it away."

"Yes," said Rollo.

"And it makes a kind of depression, or pit, in the water."

"I don't exactly understand that," said Rollo.

"Why, suppose the water were to freeze all around the log, and then you were to take the log out."

"You could not get it out; it would stick," interrupted Rollo.

"Why, the sun might shine upon the log, and warm it," said Jonas, "and so melt the ice that touched it, a little, and thus loosen it; — or, at any rate, we may *suppose* the log taken up. Now, do you not see that there would be a kind of a pit, or depression, in the ice, where the log had been?"

"Yes," said Rollo, "just of the shape of the log."

"No," said Jonas, "but just of the shape of *that part of the log* which was under water."

"Yes," said Rollo, "that is what I mean."

"Well," said Jonas, "now suppose we were to fill up this pit, or depression, in the ice, with water again, exactly full, — then the log will weigh just as much as the water poured in to fill the depression, which the log made by floating. That's the principle."

"But some logs would be heavier than others," said Rollo.

"Then they will settle down just so much the deeper. Everything that floats, will always settle down into the water until the cavity that it makes will hold just enough water, to weigh as much as the thing does itself."

"That's rather curious," said Rollo.

"Yes," said Jonas, "it is. And you might try the experiment some time in this way. Take a bowl, and fill it full of water, — exactly full. Then put it into a basin which has no water in it. Then put a block of wood very gently down into the water of the bowl."

"That will spill it over," said Rollo.

"Yes," said Jonas, "the bowl was full before, and of course some will go over; but it will be caught in the basin. Now, you see that what is spilt over will be just as much in bulk as the part of the block which is under water."

"In bulk? what do you mean by that?" asked Rollo.

"Why, in size: there will be just as

much in quantity; for the bow is as full after the block is put in as before, excepting the room taken up by the part of the block which is under water. Of course what is spilt over will be just as much in bulk as that part of the block."

"Well," said Rollo.

"Well, then," said Jonas, "if you weigh this water, which is spilt over by putting in the block, you will find that it will weigh just as much as the whole block does."

"Exactly?" asked Rollo.

"Yes, exactly, if you perform the experiment carefully."

"How did you know?" asked Rollo.

"I read it in a book which your father lent me," said Jonas. It said in that book that a floating body displaces its own weight of water. I could not understand it for a long time. I did not know exactly what was meant by *displaces*."

"And what does it mean?" said Rollo.

"Why, moves it away when it sinks down in it. A ship, for instance, settles down into the water until it makes a depression big enough to hold just as much water as the

ship weighs ;—masts, sails, rigging, cargo, and all ; and when it has settled down as far as that, it will not go any farther."

"Why not?" asked Rollo.

"Because," said Jonas, "then it presses just as heavy on the water under it as the water would, which was before in the place where it floats ; and so all will be at rest, just as before. If the ship were to press any heavier upon the water under it, than the water would which would be enough to fill up the depression which it makes, then it would sink a little deeper. And if it did not press quite so heavy, then the water under it would buoy it up a little higher. Because, you see, the water under the ship will only be at rest when the ship presses just as heavily upon it, as the water did that was in the cavity which the ship makes, before the ship came there."

Perhaps Rollo did not understand the last part of Jonas's explanation ; for just at the time he was making it, Rollo saw a chaise coming along the road, some distance before them.

"Jonas," said he, "here comes a chaise, we must turn out."

But just as Jonas was going to take hold of the reins to be ready to turn the horse out of the road, the chaise itself turned down another road, and so saved them the trouble.

So Jonas came back behind the wagon again, and Rollo asked him to go on with his explanations.

"Well, then, it follows from what I told you," said Jonas, "that if any kind of wood is just half as heavy as water, then it will have to sink down until it is just one half under water; for then it will have displaced just water enough to be equal to it in weight. If it is very light, like cork, then it will not sink down so far: my book said that cork was about a quarter as heavy as water; and so, when it floats, one quarter of it would be under water and three quarters above."

"Suppose anything was just exactly as heavy as water," said Rollo.

"Then," said Jonas, "it would sink until the top of it was just level with the surface of the water."

"Is there anything just as heavy as the water?" asked Rollo.

"Yes," replied Jonas, "*you are.*"

"I am?" said Rollo.

"Yes," replied Jonas; "that is, your body is very nearly as heavy as a mass of water of the same bulk."

"Then, if I was to get into the water, I should sink in, just level with the top of the water."

"Yes," said Jonas, "very nearly."

"Then it is not exact," said Rollo; "would it be a little more or a little less?"

"Why, it would depend upon the state of your breath," said Jonas; "sometimes a little more, and sometimes a little less."

"Why, Jonas!" said Rollo; "how can that be?"

"If you draw a long, full breath," said Jonas, "so," (and here Jonas paused a moment, and stood still in the road, and made a long and full *inspiration*, that is, drawing in of the breath;) "if you do so, the air goes into your lungs, and swells out your chest, and makes you larger and lighter. But if you breathe *out* as much of the air as you can," (and here Jonas paused again, and made a long *expiration*,) "then," he added, resuming his breath again, "the lungs are exhausted, the chest shrinks, and the body becomes heavier."

"I shouldn't think that would make much difference," said Rollo.

"Yes," said Jonas, "it makes a great deal of difference. When a boy is in the water, if he draws in as much breath as he can into his lungs, he floats. If he breathes out all the air he can, he sinks."

"Did you ever try it?" said Rollo.

"Yes," said Jonas, "very often, when I have been in the water."

"Then the body itself," said Rollo, "is just about as heavy as water."

"Yes," said Jonas, "I believe it is — just about."

"And then," added Rollo, "it will sink just even with the water."

"Yes," said Jonas, "it must sink until it takes the place of its own weight of water; and its own weight of water would be just as big as it is itself. So it must sink until it is just all in."

"That's the principle then, is it?" said Rollo.

"Yes," said Jonas, "that's the principle."

"I don't see," said Rollo, "how you can tell by it whether a tub would bear me up or not."

"Why, it shows how much the tub must sink, if you get into it," said Jonas.

"How?" asked Rollo.

"Why, the tub must sink just as much deeper than it did before you got into it, as to be equal to the size of your body. Because you see, that whether you are in a tub, or out of it, in order to be buoyed up in the water, you must take the place of as much water as will weigh just as much as you do yourself; and as water is just about as heavy as your body is, you must take the place of a quantity of water just as big in bulk. Now, don't you think a tub is bigger than you are?"

"Yes," said Rollo, "it is bigger round, but then it is not so high."

"No," said Jonas, "it is not so high, and it is very different in shape; but, making allowance for the difference of shape, don't you think that, on the whole, it is a great deal bigger than you are?"

"That is," continued Jonas, "suppose there was a wax figure, just as big as you are, and this wax figure was to be melted down, and the wax poured into the tub do you think it would fill it full?"

"No," said Rollo, "I don't think it would."

"I'm sure it would not," said Jonas. "Now, if your body would fill the tub half full, if put into it compactly, then it would sink the tub half down into the water. If you were equal in size to two thirds the tub full, then the tub would sink two thirds its depth into the water."

"And it is just so with a boat, I suppose," said Rollo.

"Yes," said Jonas; "when a man steps into a boat, he sinks it into the water, just enough more than it was before to be equal to the size of his own body. Of course, if it is a large boat, it would not have to sink so far as if it was small."

"And if it was a great ship, it would not sink any."

"Yes it would," said Jonas.

"No, it would not," said Rollo, "I know"

"How do you know?" asked Jonas.

"Why, once I went into a ship, and it did not move at all when I stepped on it."

"How did you know?" said Jonas.

"Why, I should have felt it sinking under me a little, if it had sunk any."

"Suppose that another boy had gone aboard the ship just after you did; would it have sunk any under him?"

"No," said Rollo. "There was another boy, James; and it did not sink at all."

"Suppose there had been fifty or one hundred boys," said Jonas.

"O, if there were a great many," said Rollo, "I suppose that after a while the ship would begin to sink."

"Then you think that some boys might go aboard a ship, without making it settle any in the water, but that other boys would make it settle."

"No," said Rollo, "I do not mean that some would make it settle, and others would not, but that, when there were a great many, all together would make it settle."

"Yes; but," said Jonas, "they would not all go aboard together. I mean to suppose that they come one after another; and of course, if it does not settle any at first, but afterwards does settle, there must be some one boy, whose coming aboard first makes it sink deeper into the water."

Rollo did not answer. He did not know exactly what to say to Jonas's reasoning.

"Now," said Jonas, "it is very clear that, if a thousand boys coming aboard a ship, would make it settle at all deeper into the water, then one boy must make it settle one thousandth part as much."

"Well," said Rollo, "if you do make it out so in reasoning, I know it is not so; for I have tried it."

"You are a very fine philosopher," said Jonas; and he began playfully to punch Rollo with the butt of his whip handle. "You believe your senses rather than your reason! A fine philosopher you!"

Rollo leaped over the end of the pole, which supported the end of the wagon, to get out of Jonas's way. Jonas pursued him, pointing the end of his whip handle towards him; and Rollo, with shouts of laughter, sprang across to a grassy bank by the side of the road, and ran up among some bushes, where Jonas could not reach him. Every time he drew near the road a little, Jonas pointed his whip handle towards him in a menacing manner, and so kept Rollo from returning.

Rollo ran along upon the bank thus, for some time.

QUESTIONS.

On what expedition were Jonas and Rollo sent? What accident happened to them when coming home? What part of the wagon was broken? How did Jonas remedy the difficulty? What was the supposition which Jonas made respecting the log of wood floating in the water? What is meant by *displacing*? How much water did Jonas say that the log of wood would displace? How did Jonas prove that the log would settle down into the water until it had displaced its own weight of water? What experiment did Jonas describe to be performed with a bowl full of water? What is the meaning of *bulk*? What did Jonas teach Rollo respecting the weight of the human body compared with water? How did he say it depended upon the state of the breath? How did he calculate whether a tub would be sufficient to buoy Rollo up? What is the rule in regard to the depth of water which a ship will draw? Would Rollo's going on board a ship make it sink any deeper into the water? Why did Jonas think it would? Why did Rollo think it would not?

CHAPTER XII.

DISCRETIONARY POWER.

ROLLO soon began to be tired of the bank, and wanted to return to the road again. The smile faded away from his countenance, and a serious and almost a displeased expression took its place.

"Now, Jonas," said he, "you are not fair; making me run out of the road so fast, and then keeping me in this rough place. I shall use up all my strength, and not have any left to get home with."

"So you will," said Jonas; "when we are on a forced march, we must not waste any of our strength in play. So come back, and I will not trouble you any more."

"And I think," continued Rollo, "that you ought to let me ride a little way, to pay for giving me such a run."

"Well," said Jonas, "jump in here behind, and ride on the bags."

So Rollo caught hold of the back of the

wagon, and, putting his foot upon the pole, where it came out from underneath, he climbed in. Jonas helped him a little.

"Sit over towards the wheel," said Jonas.

"Why?" said Rollo.

"Because," said Jonas, "if you sit near the pole, your weight comes upon the pole, and makes it drag harder upon the ground."

So Rollo sat over towards the wheel, which remained in its place. The wheel which came off, the boys had put in before the seat, so that it was out of the way.

Rollo rode here for some time. At length he said, —

"Jonas, would this wagon be large enough to float me, if it was in the water for a boat?"

"Yes," said Jonas, "no doubt."

"Because," said Rollo, "it will hold more than what would be equal to my bigness."

"Yes," said Jonas, "that is the way to judge; only we must make allowance for what it would sink in, of its own accord. If the wagon body were to be taken off the wheels, and put into the water, it would sink itse'f down into the water a little way, be-

cause it is made of a solid kind of wood, and has considerable iron in it. Then, after that, it would sink only enough more, if you were to get into it, to amount to just the bigness of your body, under water; and that would be only a very little way; for the wagon body is so long and broad, that it would have to sink only a very little way, to displace as much water as would equal the bigness of your body."

"Not more than an inch?" said Rollo.

"Very likely," said Jonas. "I think it very probable that an inch, or two inches, all over the bottom of the wagon, would be as much in bulk as the whole of your body. They always make ferry-boats, which are to be used for carriages and loaded teams, broad and flat, so that, when the teams are in, they may not draw much water."

"Draw much water?" replied Rollo; "what do you mean by that?"

"Why, sink down deep into the water," said Jonas. "If a boat or a vessel sinks down twenty-four inches into the water, they say she *draws* twenty-four inches. Loaded vessels draw ten or twelve feet."

"I don't see what they call it *draw*, for," said Rollo.

"Nor I," said Jonas; "only I know they do call it so. It is very important to know how much a vessel draws."

"Why?" said Rollo.

"Because then they know how deep water she must have to float in. I read in a newspaper yesterday, that there was a bar at the mouth of some harbor or other, so that vessels drawing over eight feet of water couldn't get in at low tide. But ferry-boats are made broad and flat, so that they only draw a few inches."

"Why don't they make the ships broad and flat?" said Rollo; "and then they could go over all the bars."

"Because they would not sail well," replied Jonas. "They'd go very slow, and the contrary winds would drive them all about the ocean."

"I remember that ferry-boats are flat," said Rollo. "I went over one once in a chaise. I was riding with my father."

"And did the ferry-boat sink in very deep?"

"No, not very. I thought it would sink very deep, it was such a low boat. I was afraid to have father drive in. I wanted to get out of the chaise, but my father said there was no danger. But, Jonas, why don't they have ferry-boats shaped like ships? and then we could sail across the river faster."

"Yes, perhaps the boat might sail faster where the water was deep; but then it would be constantly getting aground on the shallows, and it could not come near the shore; and so they have to make ferry-boats flat-bottomed and broad."

"But," said Rollo, "I have seen vessels, sailing in rivers, which were shaped just like ships."

"Yes," said Jonas, "vessels that sail up and down rivers may be built like ships, because they can keep in the channel, where the water is deep. But ferry-boats have to go back and forth, across, and of course have to go over shallow water, as well as deep; and so they have to build them broad and flat in order that they may not draw much water. But whatever the shape of the bottom of the boat is. when the loading is put in, it

will always make it settle down till it has crowded away just as much water as it weighs itself."

"Yes," said Rollo.

"And in the case of a man or a boy, you see," continued Jonas, "as they are just as heavy as water, they will settle down the boat till it has crowded away just as much water in bulk, as will equal the size of their bodies."

By this time, Rollo began to be somewhat tired, and he asked Jonas how much farther they had got to go. Jonas said it was about two miles

"I am sorry that our wagon got broken, Jonas," said he. "Shall *you* be able to mend it?"

"No," said Jonas, "it needs a new axletree."

"And can't you make an axletree?" said Rollo.

"No," replied Jonas, "not for a wagon; though I could make one for a cart."

"What will father do, then?" said Rollo.

"He will send it to the wagon-maker's, I suppose," said Jonas.

"Where does the wagon-maker live?" asked Rollo.

"Why, he lives on this very road," replied Jonas; "we shall go directly by his shop."

"Then why can't you leave the wagon there when you go by?" said Rollo.

"That is a question, indeed," replied Jonas; "I had not thought of that plan. But I have no authority to leave the wagon."

"No authority?" repeated Rollo.

"No," said Jonas; "my orders were to go and get some apples, and bring them home; and I have nothing to do but to obey the orders."

"But then father will only have to send the wagon right back again over the same ground to-morrow morning."

"Yes," said Jonas, "if he concludes to have it mended to-morrow, and also if he concludes to employ this man to do it. I presume he will; and if I had discretionary power, to act as I thought best, I should leave it; but when no discretionary power is given, then the only way is to obey orders. That's the rule at sea, and it ought to be the rule on land."

"Yes, but, Jonas, you told me once yourself," rejoined Rollo, "that you always had discretionary power in emergencies; you said that it was understood and implied between you and father, that when anything unexpected occurred, you were to act according to your best discretion."

"Did I?" said Jonas.

"Yes," said Rollo, positively.

"Well," said Jonas, "I suppose I have some discretionary power; but that's a kind of power which it is rather dangerous to use."

Here the conversation stopped, and the boys walked along for some time in silence. They were both weary with walking, and felt, on that account, less inclined to talk. After some time, Rollo said, —

"Well, Jonas, what do you think, on the whole, that you shall do about the discretionary power?"

"Why, I think, on the whole," replied Jonas, "that I shall take the responsibility of using it."

"And leave the wagon at the wagon-maker's?"

"Yes," said Jonas, "only I shall leave such directions as shall make it perfectly safe."

The boys, soon after this, arrived at the wagon-maker's. It was a shop near a mill, and it had a lathe and a circular saw, which were moved by water. Rollo went down under the shop with Jonas, to see the water spouting with great force against the water-wheel.

"That spouts out with rather more force than the water did from your dam," said Jonas.

"Yes, indeed," said Rollo.

"That is because there is a greater head of water," said Jonas.

"Yes," said Rollo, "it is pressed by a higher column. I wonder how high it is."

When they went up into the shop again, Jonas asked the man, and he said that they generally had about six feet of water. When Rollo heard this, he was not surprised that the water spouted out against the wheel with so much force.

Jonas ascertained from the wagon-maker how much it would cost to mend the wagon

and also when he could do it. He then told him that he might begin to mend it at nine o'clock the next morning, unless he heard from Rollo's father before that time. "In case he does not wish to have it mended," said he, "I can come over early, and let you know."

Then Jonas took the harness off the horse, and put it in a corner of the shop. He borrowed a piece of a blanket of the wagon-maker, and placed it across the horse's back, and then he put Rollo on. Thus Rollo had a ride the rest of the way. He walked the horse, to keep in Jonas's company, until they had got within about half a mile of home; and then he trotted on, to tell them that Jonas was coming.

QUESTIONS.

When Rollo got into the wagon, where did he take his seat, at first? What change in it did Jonas propose? For what reason? What question did Rollo ask about the wagon? What was Jonas's answer? Why did he think that the wagon would sink but a little way with Rollo's weight in it? What did he say about the construction of

ferry-boats? What is meant by a vessel's drawing six feet of water? Why are not ships made flat-bottomed, like ferry-boats? What led to the conversation about *discretionary power*? Was Jonas reluctant to use such power? What precautions did he take to make his use of it safe?

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